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# Validation Studies at Deep Creek, Curlew Valley

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# 1971 PROGRESS REPORT

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## ABSTRACT

One of the main purposes of the study was to characterize an entire desert stream ecosystem as to biotic community, and the environmental conditions affecting the community. Four sampling stations were established, one in each of the main physiographic sections of Deep Creek. The most important natural factors influencing the stream are annual differences in solar radiation, temperature extremes, and runoff patterns. The stream is also affected by regulations of stream discharge (reservoirs and irrigation withdrawals) and use of the watershed by cattle.

The most outstanding event to occur during 1971 was the March flood which drastically altered conditions at Stations 1 and 2. Two reservoirs dampened the effects of the flood waters on Stations 3 and 4. Turbidity at the various stations was related not only to the flood and increased discharges of water but, during the year, to presence of cattle along the stream and decreases in the amount of aquatic macrophytes. Water temperature, which was suddenly lowered by the flood waters from melting snow, usually ranged from freezing in the winter to 25°C in the summer.

Benthic invertebrates were extensively sampled. At Station 1 there appeared to be 3 times more invertebrates in riffles as compared to reach areas. These numbers attained a peak in August in the riffles whereas in the reach areas of the stream peak numbers appeared during January. The four most abundant (densities greater than 5000/$m^2$) at Station 1 were chironomids, *Hyalella azteca, Simulium* sp. and *Baetis tricaudatus*. All were found in greater density in the riffles, with chironomids dominating in both areas. At Stations 2 and 3 predominant species diversity increased, but dropped down for Station 4. Throughout the stream *Hyalella* and chironomids were abundant. A length-frequency histogram for *Hyalella* indicated that recruitment from young probably occurred in August with juveniles overwintering to become adults in spring. Average standing crops, production, and turnover rates were calculated for the major invertebrates.

Of the five fish species collected in the stream, *Rhinichthyes osculus* is the most important. Numbers and dry weights were recorded for this species for each station. These data showed recruitment from reproduction as beginning in June.

Sampling and calculations were made to estimate the amount of allochthonous matter added to stream by cattle use of the area. Spring runoff caused much of their fecal material to reach the stream. Dissolved organic carbon recorded at Stations 1 and 4 respectively were 461.3 $g/m^3$ and 483.4 $g/m^3$.

Periphyton and macrophyte concentrations differed at each station, with macrophyte biomass reaching the highest levels during the summer in upstream station. There was a drastic reduction of this level after the annual introduction of cattle into the area in August. The dominant species of macrophytes were *Chara*, *Eleocharis* and two species of *Potamogeton*. Community metabolism measurements were made on the macrophytes. The results indicated that carbon, rather than phosphorus or nitrogen, appeared to be the main limiting factor during the growth season in Deep Creek.

# INTRODUCTION

This investigation was one of several being conducted in the arid region of the western United States as a part of the International Biological Program -- Desert Biome aquatic studies. It was also one of the few studies of a total stream ecosystem being done under the auspices of the U.S./I.B.P. One purpose of these studies was to provide information on the aquatic portion of the land-water interactions which are a central focus of the watershed-oriented Analysis of Ecosystems program; another was to describe the structure and function of several important kinds of desert aquatic ecosystems as a contribution to the goals of the Productivity Freshwater (PF) section of IBP.

The specific purposes of the present study were to determine as completely as possible the composition of the biotic community in a small desert stream, to define the environmental conditions under which the community operates, to determine the response of the community to certain environmental factors including temperature, flow, substratum, and selected nutrients, to establish a detailed account of the major paths of energy flow, including an assessment of the rates involved and the annual production, and to examine several of the more important interchanges between the stream and the land. As originally planned the study was to continue for 5 years, however, due to financial constraints it is being discountinued at the end of the second year.

Since one of the main purposes of this study was to characterize an entire desert-stream ecosystem, sampling sites were established in each of the main physiographic sections of Deep Creek lying within the sagebrush-dominant plant zone and bounded by the 41 cm (16 in.) precipitation isohyeth. The sections ( and the corresponding sites) are recognized by a combination of factors including climate, terrestrial vegetation, stream-flow characteristics, and type of substratum. Four such physiographic units are clearly discernible and, in addition, incorporate unique features which have proven useful in furthering understanding of this type of ecosystem in response to several common perturbations or stresses. Natural temporal factors which exert important influences in the Deep Creek system are annual differences in solar radiation, temperature extremes, and runoff patterns (degree of flooding). Naturally occurring spatial variations were utilized to compare the effects of a relatively warm (17°C), constant temperature regimen with that of a normal seasonal fluctuation, and to study the consequences of regulating stream discharge, and the effects (on the stream) of the use of the watershed by cattle (including direct disturbance and the input of organic matter).

Groundwork for this project was laid during the latter half of 1969 and the early part of 1970. Regular sampling of several important parameters began in June,1970, but the simultaneous measurement of most of the components was not possible until September. Therefore, August,1971, marks the completion of the first full year of intensive censusing of all of the major components of the Deep Creek ecosystem (Fig. 1).

On the basis of the first year of study an "event chain" was developed (Fig. 1) which made it possible to reduce the frequency of sampling. Censusing activities were scheduled to correspond with or bracket important events. These changes are reflected in the sampling schedule beginning with September, 1971. Important aspects of the schedule include intensive sampling of all parameters during the main period of aquatic plant growth (April - September) and of appropriate indicators before and after the period of maximum runoff, before and after the annual introduction of cattle, during the period of minimum discharge and maximum temperatures, and following the cessation of autochthonous plant production in the autumn.

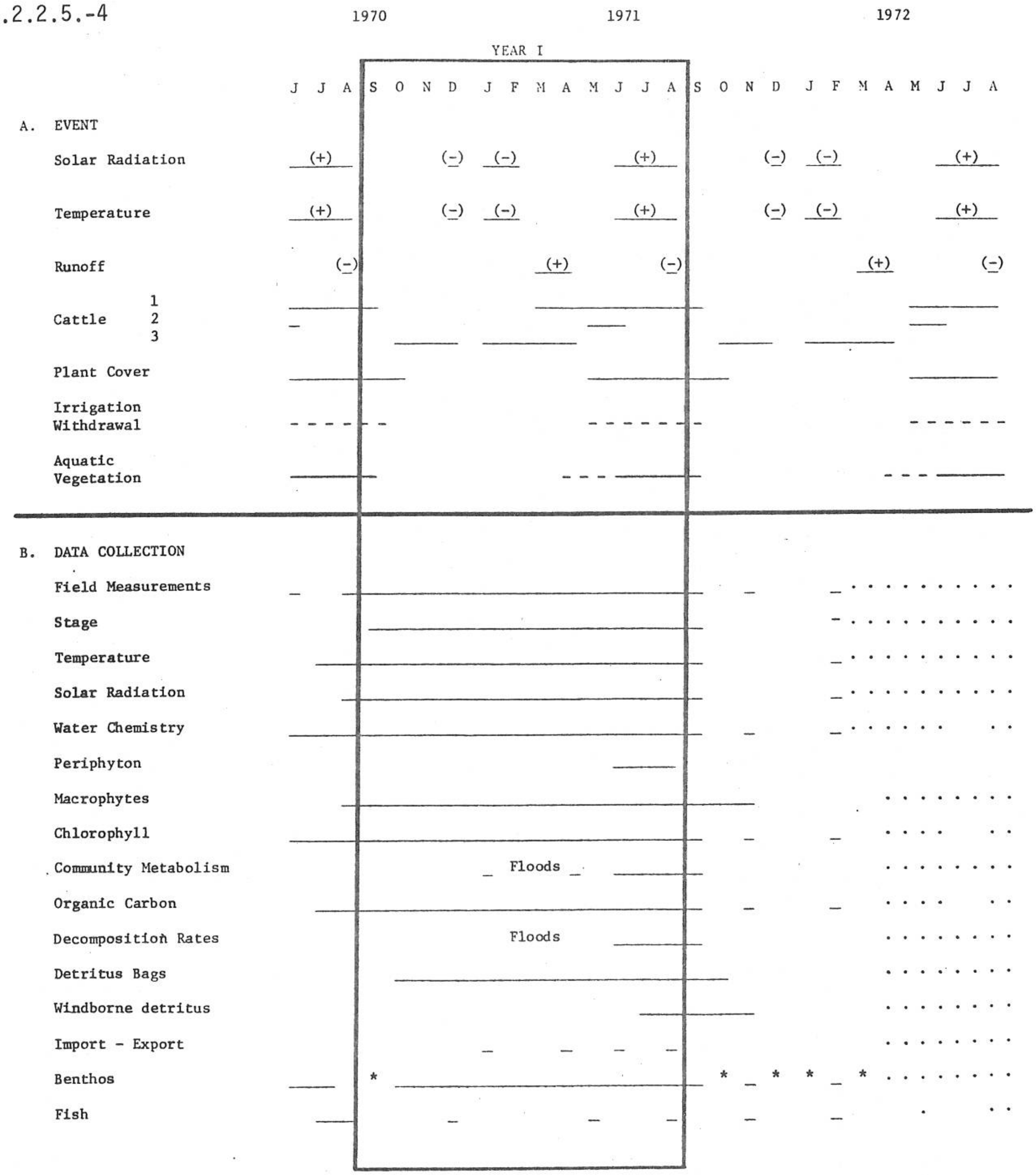


Figure 1. Event chain (A) and availability of data (B) for Deep Creek, Curlew Valley, IDaho-Utah. In part A the solid lines refer to the continuous effect of an event over a period of time; broken lines indicate an intermittent or variable effect. A (+) indicates a period of maximum values; a (-) delineates a period of minimum values. Solid lines in part B indicate completed measurements and dotted lines, collections planned for the duration of the project; collections which have been made but which are not yet processed are marked with an asterisk. The large rectangle delineates the first 12 full months for which data are available on most of the parameters examined.

# OBJECTIVES

As with all of the aquatic investigations in the Desert Biome, the objectives of the Deep Creek validation study were multifaceted and were set forth by:

1. The productivity section for freshwater communities of the national IBP Committee (IBP News 1967 No. 9, pp. 40-46).

    a) To study the basic factors of production and metabolism, at all trophic levels. "Investigations should be oriented so as to lead to an increased knowledge of factors governing biological productivity and to point to methods for obtaining more food (by increasing productivity) and additional clean water (by reducing productivity and pollution)."

    b) To study each of the major trophic levels in respect to: community structure, biomass, rates of biomass changes, factors controlling biomass changes, utilization efficiencies.

    c) to investigate specific topics including:
        transfer of material from land to freshwater
        backflow of energy from water to land
        silt
        effects of artificial heating
        detritus
        flowing waters

2. The Desert Biome Central Office.

    a) To conduct an initial inventory (standing crop measurements) of energy, nitrogen, phosphorus, carbon and water in as many as possible of the biotic (species) and abiotic components of the site.

    b) To make periodic standing-crop estimates of the major biotic and abiotic components of the system.

    c) To make periodic measurements of the physical factors and inputs in the site.

    d) To develop equipment and facilities to accomplish the above.

The specific components detailed for analysis are given in the Research Design for the Desert Biome: Aquatic Studies.

# METHODS

The following project list enumerates the specific methods being used for the site.

*Benthic Aquatic Invertebrate Numbers* (DSCODES A3UMLD1 through A3UMLD4)

Data Recorded: All organisms were counted into 1-mm size groups.

Experimental Methods: A Hess, 1/16m$^2$ bottom sampler (.390-mm mesh) is used to collect bottom samples which are preserved with 10% formalin and returned to the lab in quart containers. Samples are washed through a sieve series (3.36, 1.68, 0.841, 0.351 mm), sorted to taxa and identified and counted under a binocular microscope. Organisms are identified using Edmondson (1966), Pennak (1953), Usinger (1963). Most species identifications were made or verified by recognized taxonomic authorities based on adult specimens where necessary.

Experimental Design: Stratified random samples are taken.

Literature Citations: Edmonson, W. T., Fresh Water Biology, John Wiley & Sons, Inc., 1966, New York; Pennak, R. W., Fresh Water Invertebrates of the United States, The Ronald Press Co., 1953, New York; Usinger, R. L., Aquatic Insects of California, University of California Press, 1963, Berkeley, California.

*Standing crop (chlorophyll a) of the Periphyton* (DSCODES A3UMLF1 through A3UMLF4)

Data Recorded: Mg of chlorophyll *a* of 1/32m$^2$ area and 4cm$^2$ area of periphyton is converted to mg chlorophyll *a*/m$^2$. Mean of N determinations = + OR - 0.26 ug at the 5 ug level.

Experimental Methods: Redwood trays (1/16m$^2$) containing acid-washed natural rocky substrate are left in the water for 6 weeks (Waters, 1961) at stations 1, 2, 3, 4. All of the substrate in half (1/32m$^2$) of the tray is removed, placed in dark bottles and covered with 90% acetone. The mud substrate at stations 3 and 4 is sampled with a 4cm$^2$ core sampler and treated as above. Transport to the lab in an ice cooler. Extraction takes place in the dark, under refrigeration for 24 hours. Spectrophotometric determination is done with a Beckman DB-G grating spectrophotometer using the techniques and formulae presented by Strickland and Parsons (1968). Duplicate samples are taken and processed.

Experimental Design: Sampling of chlorophyll *a* of periphyton after 6 week colonization on acid-washed natural substrate. Periphyton of the natural mud substrate is also examined for chlorophyll *a*.

Literature Citations: Strickland, J. D. H., T. R. Parsons, A Practical Handbook of Seawater Analysis. Fisheries Research Board of Canada, 1968, Ottawa, Canada; Waters, Notes on the Chlorophyll Method of Estimating the Photosynthetic Capacity of Stream Periphyton. Limnology and Oceanography, 6:486.

*Biomass of Benthic Aquatic Invertebrates* (DSCODES A3UMLD5 through A3UMLD8)

Data Recorded: Weight of all organisms in 1-mm size groups.

Species: Refer to DSCODES A3UMLD1 through A3UMLD4.

Experimental Methods: A Hess 1/16m$^2$ bottom sampler (0.390-mm mesh) is used to collect bottom samples, which are preserved with 10% formalin and returned to the lab in quart containers. Samples are washed through a sieve series, (3.36, 1.68, .841, .351 mm) sorted to taxa, identified, sorted to 1mm size groups and dried at least 24 hours at 60°C, and weighed on a Mettler H6 balance to the nearest 0.0001gm.

Experimental Design: Stratified random samples are taken.

*Standing Crop of Organic Carbon: Attached, Particulate, and Dissolved* (DSCODES A3UMLF5 through A3UMLF8)

Data Recorded: Organic carbon (amount of organic carbon of 1-cm$^2$ area of periphyton is converted to energy units, Kcal/m$^2$, of rocky substrate. Particulate carbon from 500 ml and dissolved from 25 ml of water is converted to energy units of Kcal/m$^3$ of stream water. + or - 0.5% of the mean value is the precision--Maciolek (1962).

Experimental Methods: Periphyton samples are taken from rocky substrate after a 6-week colonization time and water samples are taken from midstream, after which all samples are placed in the dark under refrigeration for transport to the lab where they are stored under the same conditions. The particulate matter is removed by filtering the water through a 0.8 micron membrane filter and the dissolved material is determined from the filtered water. Attached, particulate and dissolved organic carbon is determined within 48 hours using the semimicro method of quantitative dicromate oxidation as developed by Maciolek (1962).

Experimental Design: Random sampling of periphyton after colonization for 6 weeks on natural (acid-washed) substrate. Particulate and dissolved organic carbon are determined from water samples taken in midstream.

Literature Citations: Maciolek, J. A., Limnological Organic Analyses by Quantitative Dichromate Oxidation, Bureau of Sport Fishers and Wildlife, 1962, Washington, D.C.

*Numbers and Biomass of Periphyton* (DSCODES A3UMLG1 through A3UMLG8)

Data Recorded: Biomass (g/$m^2$ organic matter, relative abundance per species)

Species: *Cladophora, Spirogyra, Navicula, Gomphonema, Nitzschia, Achnanthes, Cocconeis.*

Experimental Methods: Redwood trays (1/16$m^2$) containing acid-washed natural rocky substrate are left in the water for 6 weeks at stations 1, 2, 3, 4. Substrate with attached periphyton is removed from half (1/32$m^2$) of the tray, placed in a plastic bag, and returned to lab. Periphyton scrubbed from substrate placed in container, dried and ashed. Subsample collected for slide preparation and enumeration of species.

Experimental Design: Paired sets of trays are placed in a representative section of the stream and allowed to colonize for 6 weeks.

*Biomass of Aquatic Macrophytes* (DSCODES A3UMLH1 through A3UMLH4)

Data Recorded: Biomass (g/$m^2$ organic matter (ash free dry weight)).

Species: *Eleocharis, Potamogeton, Chara* (Macrophytic Algae), *Veronica, Rorippa.*

Experimental Methods: All vegetation removed from 1/16$m^2$ area using a Hess sampler, placed in plastic bags and returned to lab. Sampels washed and sorted into species, dried and ashed.

Experimental Design: Sampling carried out in regions of reduced flow along borders of stream and in thalweg, at randomly selected points relative to a permanent check point.

*Numbers and Biomass of Fish* (DSCODES A3UMLI1 through A3UMLI4)

Data Recorded: Length, weight, (organisms measured in millimeters to the nearest millimeter and weighed in grams to the nearest 0.1 gram).

Species: *Rhinichthys osculus, Cyprinus carpio, Gila atraria, Micropterus salmoides, Perca flavescens.*

Experimental Methods: An electrofisher (AC 110V or DC 325V) is used to collect fish from 100-m long sections at each station. Three passes are made through each section with the fish from each pass being censused separately. Fish are counted, weighed and measured.

Experimental Design: A regression line is plotted to obtain an estimate of all of the fish in a section.

*Air and Water Temperatures* (DSCODES A3UMLJ1 through A3UMLJ4)

Data Recorded: Air temperature, water temperature, (°F).

Experimental Method: Thermograph, dual pen, continuous recording, seven-day clock (Weathermeasure Corp. No. T601-S-W). Instrument located in an instrument shelter. Probes are located in identical shields at all four stations. Water temperature is taken near the water-substrate interface and air temperature in a shaded area approximately 2 m above the ground.

*Solar Radiation - Total Incoming* (DSCODES A3UMLJ5 through A3UMLJ8)

Data Recorded: Solar radiation in Kcal when multiplied by instrument constant. Constants are as follows: Station 1, 0.369; Station 2, 0.369; Station 3, 0.360; Station 4, 0.373.

Experimental Methods: Pyrheliograph (actinometer), range 360-2000 MU, continuous recording, seven-day clock (Weathermeasure Corp. No. 401).

Experimental Design: Instrument located on top of instrument shelter approximately 3 m above the ground, protected with a bullet-resistant case. Shelters are located at stream side.

*Water Level* (DSCODES A3UMLK1 through A3UMLK4)

Data Recorded: Water depth, (once calibration is completed results can be given as discharge in $m^3$), continuous.

Experimental Methods: Stage recorder, metric, continuous recording, seven-day clock (Weathermeasure Corp. No. F552-M).

Experimental Design: Instrument and stilling well are located in instrument shelter. Natural controls are used at all stations except station 1 where a weir has been installed. Readings are checked weekly against a staff gauge located in the stream opposite the instrument shelter. Charts changed weekly.

*Field Measurements* (DSCODES A3UMLL1 through A3UML14)

Data Recorded: Depth, width, current velocity, stage height, discharge, temperature of water, present temperature (weekly).

Experimental Methods: Field measurements are taken at four stations along the course of Deep Creek. These measurements include: Depth - Five depths, in centimeters, are measured across the width of the stream at an assigned location at each station. Current velocity is measured as the number of revolutions per 50 seconds of a calibrated propeller using an OTT C-1 Current Meter. Stage height is read in centimeters directly from a 2-m stick permanently fixed in the stream bed. Discharge is calculated using the formula: discharge-depth * width * velocity, where depth is converted from centimeters to meters, width is directly expressed in meters, velocity is converted from feet per second to meters per second, discharge is expressed as $m^3$/sec. Temperature of water is read in °F from a permanent, instream, maximum-minimum thermometer. This measurement gives both max-min and present water temperature. Both present air and water temperatures are taken from a hand-held centigrade thermometer.

*Water Chemistry Analyses* (DSCODES A3UMLM1 through A3UMLM4)

Data Recorded: Ammonia, Nitrate, Nitrite, Phosphate, Calcium, Magnesium, Iron, Silica, Sulfate, Carbonates, Hardness, Specific Conductance (monthly).

Experimental Methods: One liter samples are taken from the center of the stream in plastic bottles, treated with 5 ml of chloroform, and returned to the laboratory for analysis the next day. The methods used for analysis are as follows:

Nitrogen
- Ammonia - direct nesslerization (Hach Chemical Company, 1969)
- Nitrate - cadmium reduction method (Hach Chemical Company, 1969)
- Nitrite - diazotization method (Hach Chemical Company, 1969)

Phosphate - Ortho and Meta - stannous chloride method (Hach Chemical Company, 1969)
Calcium - (Golterman, 1969)
Magnesium - Golterman, 1969)
Iron - phenanthroline method (Hach Chemical Company, 1969)
Silica - colorimetric heteropoly blue method (Hach Chemical Company, 1969)
Sulfate - turbidimetric method (Hach Chemical Company, 1969)
Carbonates - (Am. Publ. Health Assoc., 1965)
Hardness - EDTA Titrimetic method (Am. Publ. Health Assoc., 1965)
Specific Conductance - (Am. Publ, Health Assoc., 1965)
pH - (Am. Publ. Health Assoc., 1965)

Literature Citations: American Public Health Association. 1965. Standard Methods for the Examination of Water and Wastewater. Am. Publ. Health Assoc., Inc., 769 pp; Golterman, H.L. 1969. Methods for Chemical Analysis of Fresh Waters. IBP Handbook No. 8. Blackwell Sci. Publ. 172 pp.; Hach Chemical Company. 1969. Colorimetric Procedures and Chemical Lists for Water and Wastewater Analysis. Hach Chemical Co. 102 pp.

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# F I N D I N G S

## OUTLINE

A. Physical factors

B. Chemical factors

C. Fish

D. Benthos

  1. Species and numbers
  2. Biomass and production

E. Decomposers

F. Allochthonous matter

G. Import-export

H. Periphyton

I. Macrophytes

J. Community metabolism

# FINDINGS

Emphasis in this progress report is on the first full year of data collection (Fig. 1); results prior to that period are given in the 1970 report and subsequent data will be presented at the completion of the project (second full year). As an aid in the interpretation of the data, the locations of the study sites are given in Figure 2 and a mental perspective is provided by the photographs in Figure 3.

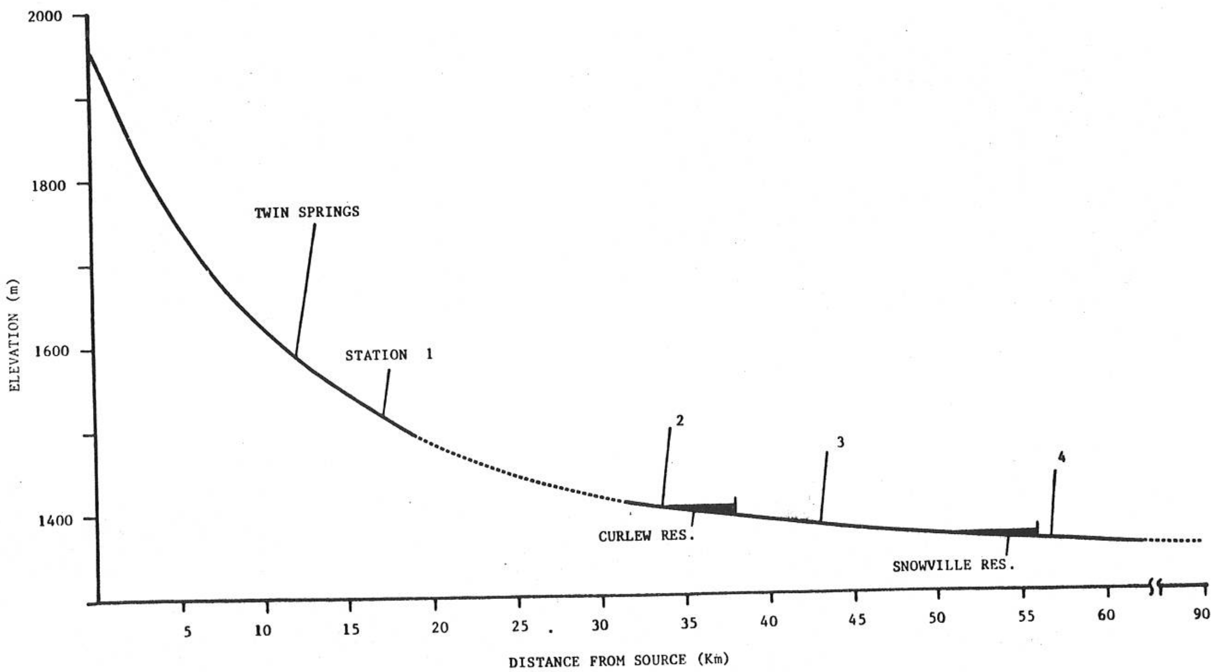


Figure 2. Vertical profile of Deep Creek, Curlew Valley, Idaho-Utah showing location of the study sites, irrigation reservoirs, and intermittent sections (broken lines).

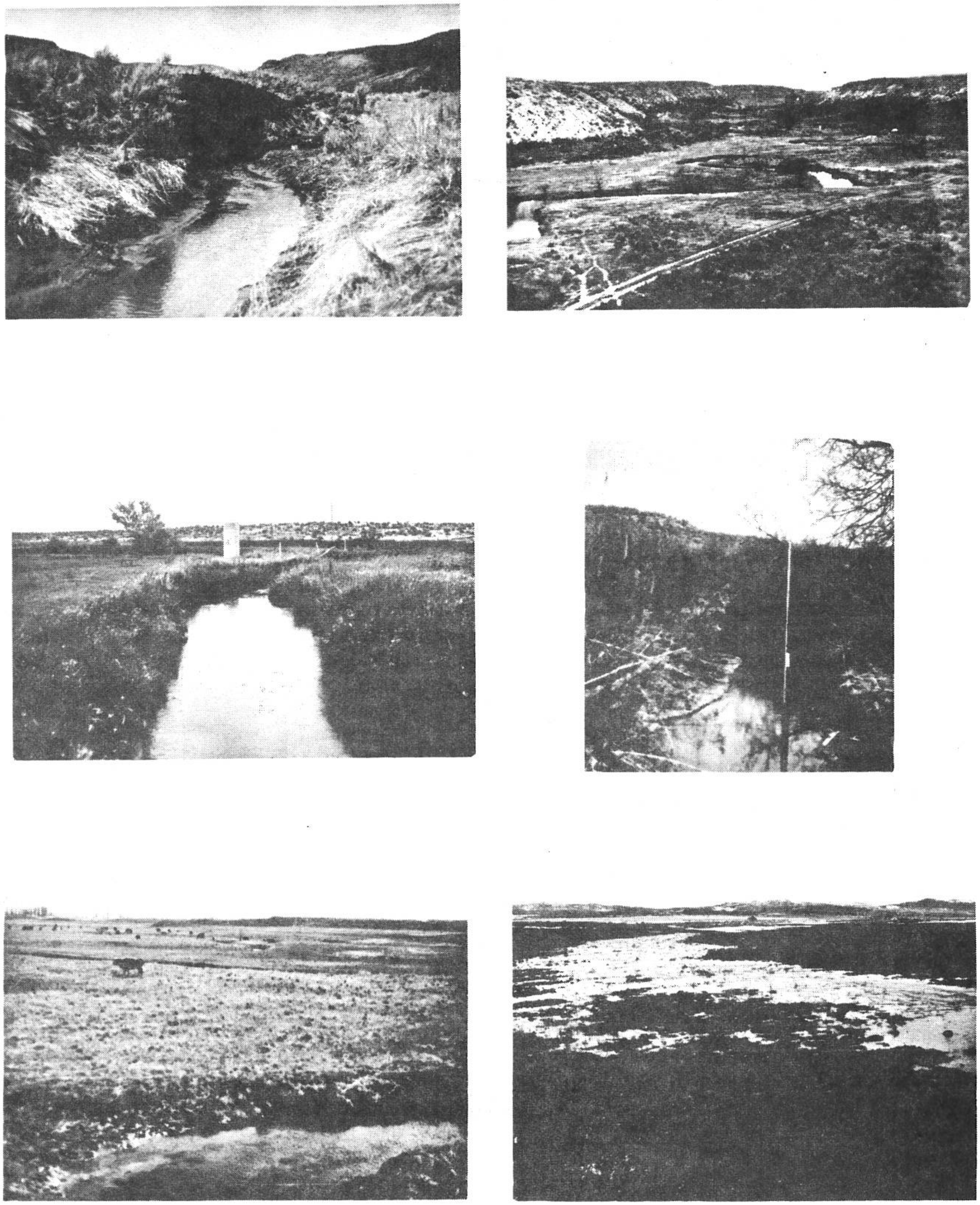

Figure 3. Deep Creek, Curlew Valley, Idaho-Utah. A.(top left) Station 1; B. (top right) Station 2; C. (center left) Station 3; D. (center right) Station 4; E. (lower left) Cattle use adjacent to Station 3; F. (lower right) Surface drainage from tilled and grazed lands.

A. PHYSICAL FACTORS

Variations in stream discharge are shown in Figure 4 and summarized in Table 1. No data are available for early September, 1970, and January, 1971, when the current meter was inoperable. Mean volume of flow was greatest at station 2 in spite of reductions due to irrigation withdrawal during most of the summer. Date of initial draw-down of the stream was delayed by about a month because of an unusually wet and cool spring. One of the most far-reaching events, especially at station 2 where severe changes occurred, was the March 1971 flood. At station 2 the flood actually peaked on March 13 but the discharge could not be determined due to the depth of the water. The effects of the flood at station 3 were delayed ( and mitigated) by Curlew Reservoir, which was well below capacity at the start of the runoff period.

Decreased discharge downstream from station 2 outside the irrigation season largely is due to reservoir storage; subsurface aquifers help to maintain flow rates at station 3 near constant levels throughout the summer. Reduced flow during the summer at station 4, down from that at station 3, may be due to evapo-transpiration. However, flow at station 4 is regulated by water from a storage reservoir; in 1971 such regulation began about May 15. The dampening effect of the two reservoirs is illustrated by the March discharge values when the stream was in flood; the effect of the flood was completely dissipated by the time station 4 was reached. Thus the normal cleansing effect of spring floods has been considerably reduced below station 2 and a thick deposit of sediments has tended to build up in these areas over the years.

There was a reasonably close relationship between turbidity and discharge at station 1 (Fig. 4A). The relatively high summer values and the increase in turbidity in July was due to the presence of cattle upstream. Turbidity at station 2 (Fig. 4B) was low at all times except during the period of flood when the stream was receiving land drainage from the intermittent section above. Except for the flood period, turbidity levels at station 3 (Fig. 4C) were independent of discharge. Values declined in the summer with the onset of aquatic macrophyte development and increased to sustained highs with the disappearance of plant cover in the autumn. High turbidity values were obtained most of the time at station 4 (Fig. 4D) although there was some indication of additional increase during periods of increased discharge.

Water temperatures underwent a relatively wide range of variation during the year from freezing conditions in winter to over 25°C in summer (Table 1). Maxima were associated with periods of low flow in the summer. Temperatures at station 2 normally were constant around 17°C due to the spring-fed nature of the stream but this constancy was severely altered by reduced water levels from irrigation withdrawal and by the overriding effect of snowmelt runoff during spring flood.

Data on solar radiation was processed only for station 2 since values at the other stations appeared to be similar (except for variations associated with local topographic differences). Values ranged from mean monthly minima of 1373 and 1368 kcal/m2/day in December, 1970, and January, 1971, respectively, to 5554 and 5694 kcal/m2/day in June and July, 1971 (Fig. 5).

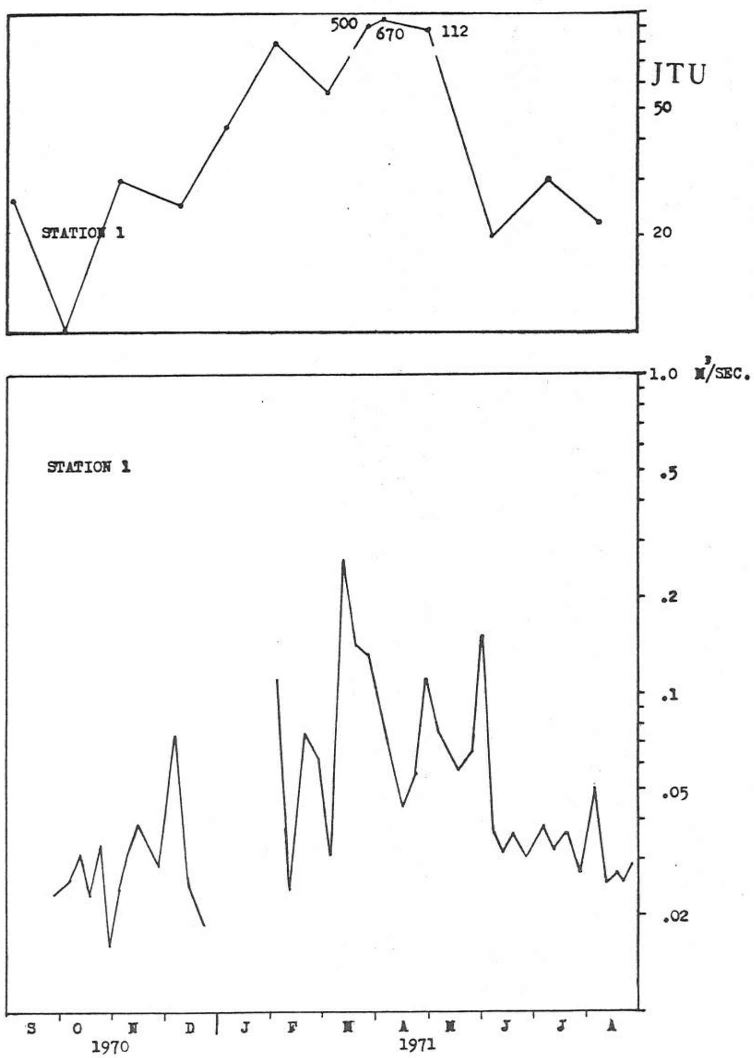


Figure 4A

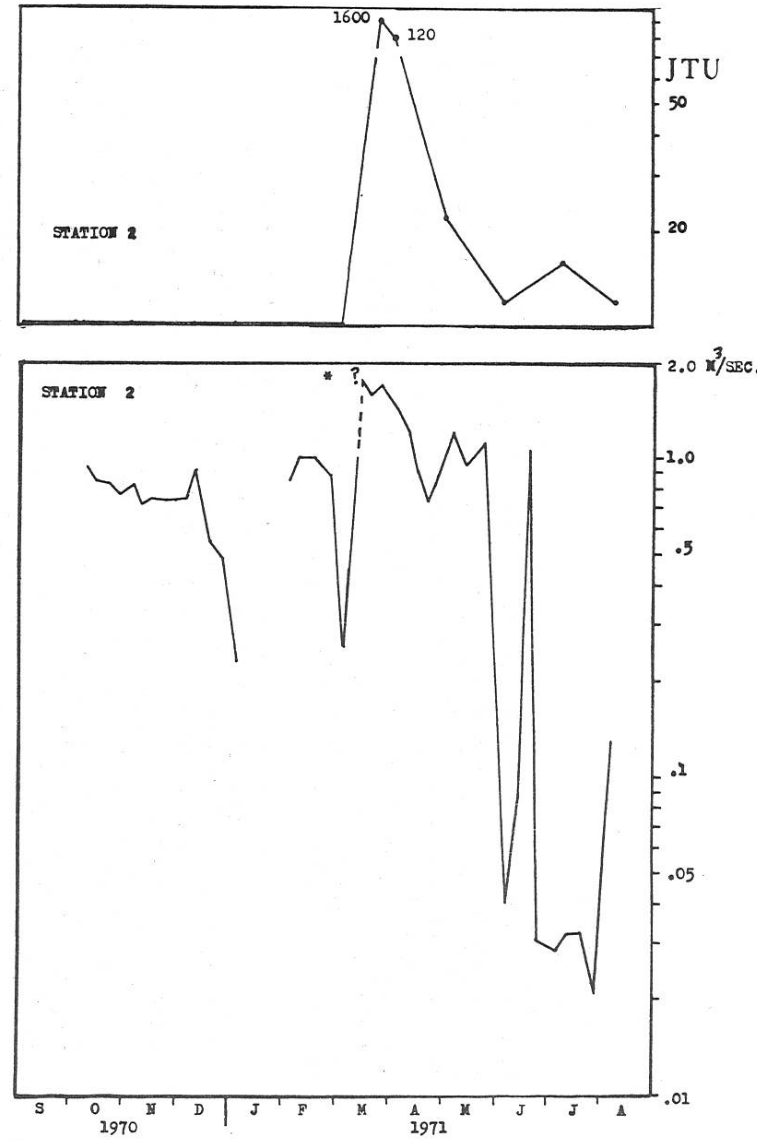


Figure 4B.

Figure 4. Turbidity and discharge at station 1 through 4 (Figure 4A through 4D, respectively) of Deep Creek, Curlew Valley, September, 1970, through August, 1971.

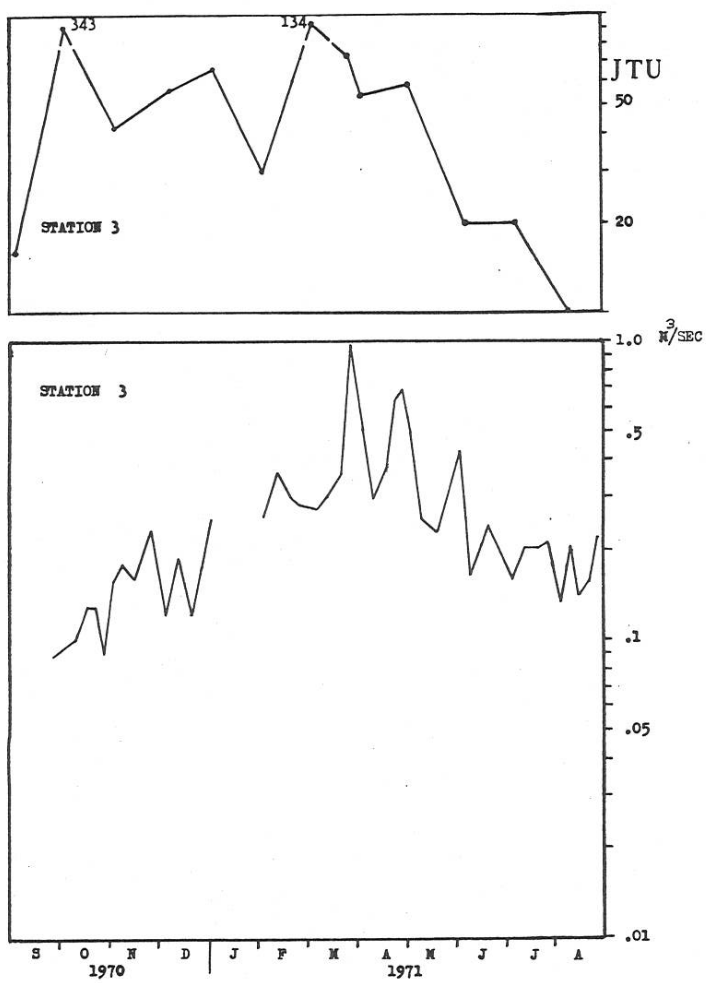


Figure 4C.

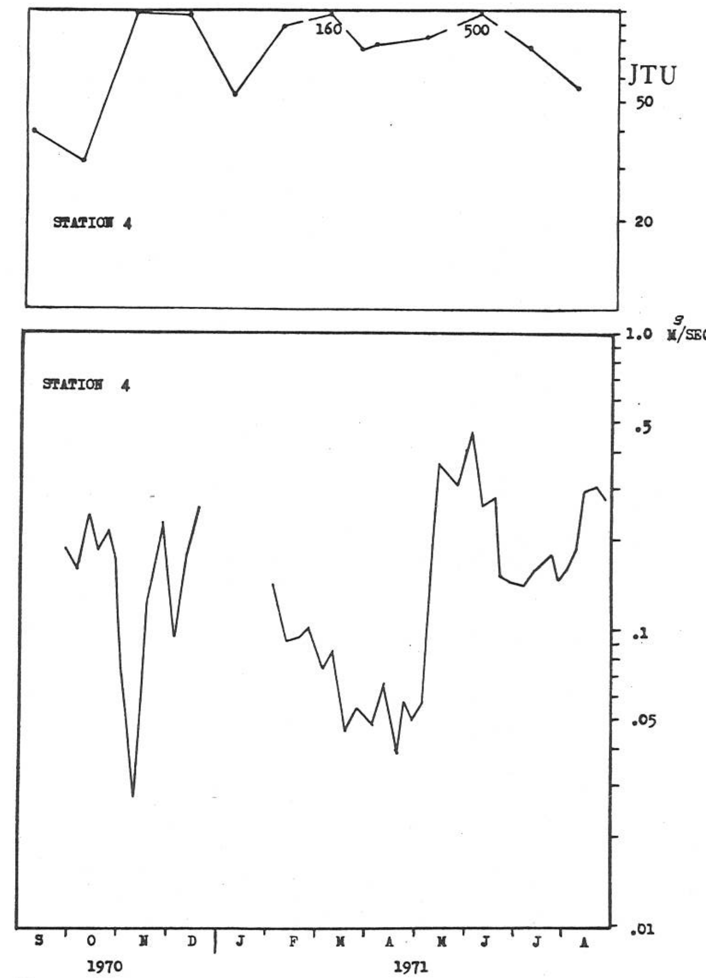


Figure 4D.

Figure 4. Continued.

Table 1. Summary of flow and temperature conditions in Deep Creek, Curlew Valley, for the period September, 1970, through August, 1971. Determinations were made each week; temperatures were obtained from maximum-minimum recording thermometers.

| | Station 1 | Station 2 | Station 3 | Station 4 |
|---|---|---|---|---|
| Discharge ($m^3$/sec) | | | | |
| Mean | .056 | .702 | .262 | .162 |
| Maximum | .265 (13 Mar., 71) | 1.700 (28 Mar., 71) | .988 (28 Mar., 71) | .461 (1 June, 71) |
| Minimum | .016 (31 Oct., 70) | .021 (26 July, 71) | .089 (26 Sept., 70) | .028 (14 Nov., 70) |
| Temperature Extremes (°C) | | | | |
| Maximum | 31.9 (29 June) | 29.2 (26 July) | 26.6 (26 July & 10 Aug.) | 29.6 (29 June) |
| Minimum | -4.2 (Jan.-Feb.) | 2.7 (20 Mar.) | -2.2 (17 Jan. & 7 Feb.) | -3.5 (13 & 20 Feb.) |

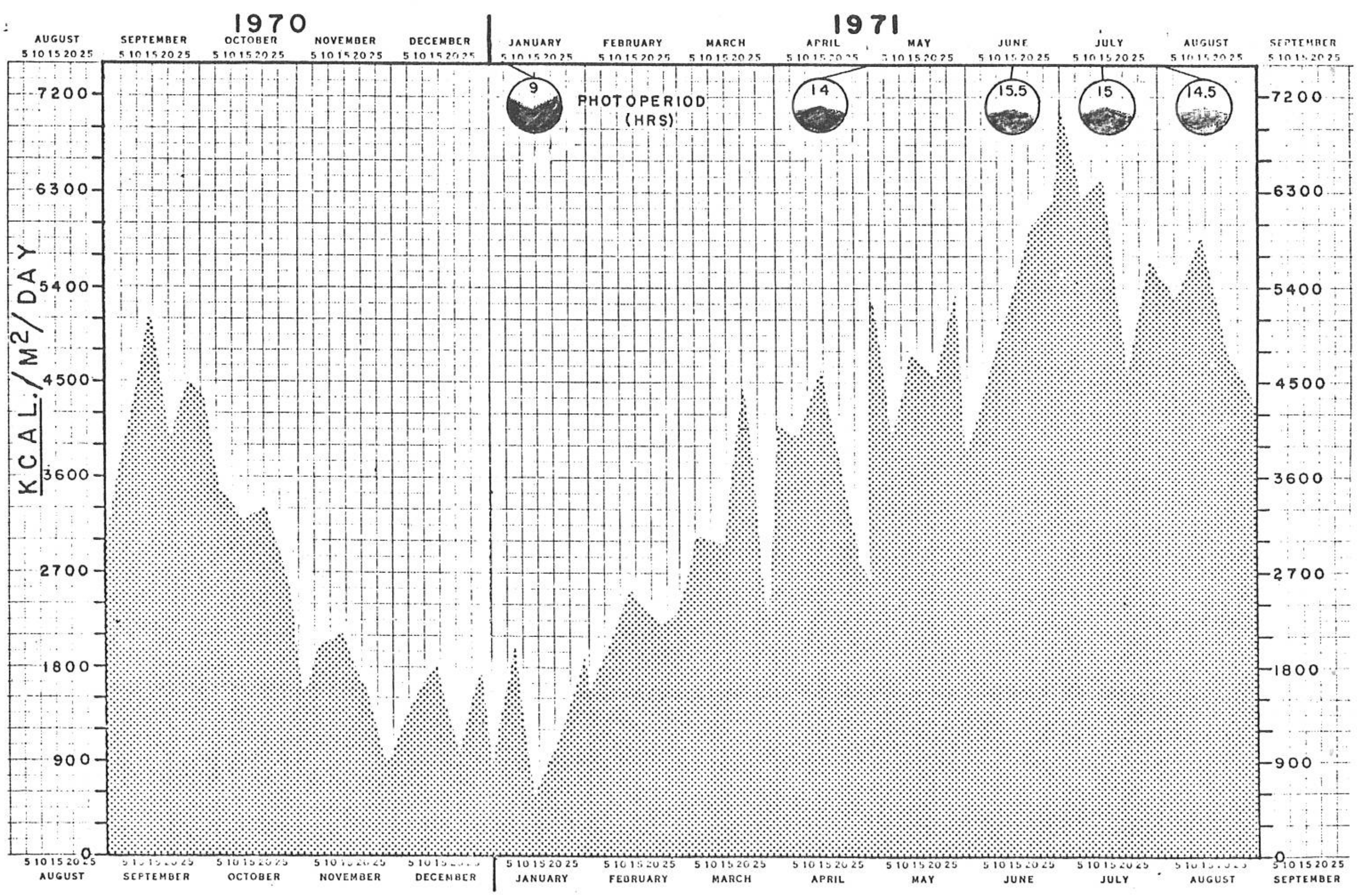


Figure 5. Solar radiation at Deep Creek, Curlew Valley station 2 from September, 1970, through August, 1971.

B. CHEMICAL FACTORS

Data on chemical composition of the water is summarized in Table 2; a graphical display of the monthly variations is available from the Biome Central Office as part of the data reduction program. Mean concentrations of total dissolved solids (estimated from specific conductance measurements) were more than twice as great at the two downstream stations. Most of the difference appears to be due to increases in sodium chloride and calcium-, magnesium- and sodium-sulfate levels; mean carbonate values remained quite constant at all stations. Our values are in good agreement with those obtained by the U.S.G.S. for samples collected in the vicinity of station 4 on 17 June, 1949, and 11 October, 1967 (Bolke and Price, 1969). In addition, they measured sodium (226 and 299 mg/l) and potassium (19 and 13 mg/l) for the two dates (respectively).

Mean ammonia levels were noticeably high at all stations but especially at stations 3 and 4. Mean nitrate values were highest at stations 1 and 2 but reached lows at all stations from June through August. Lowest mean ammonia and phosphate concentrations occurred at station 2. Nitrate appeared to be a possible limiting factor during the growing season but not phosphorus. However, nitrate-nitrogen supplies seem to be adequately supplemented by ammonia sources of nitrogen. One analysis for mercury content of the bottom sediments in April ,1971, yielded .00016 (station 1), .00023 (station 2), .00020 (station 3) and .00044 (station 4) milligrams per gram of sediment. There was no clear evidence that the March floods had any effect on the chemical parameters of the water except for phosphates (which increased) and iron (which decreased).

Table 2. Range and mean of water chemistry values for Deep Creek, Curlew Valley, during the period September 1970 through August, 1971.

| Lab Measurements | Station #1 | | | Station #2 | | | Station #3 | | | Station #4 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | High | Low | Mean | High | Low | Mean | High | Low | Mean | High | Low | Mean |
| Calcium | 150.000 | 40.000 | 80.300 | 140.000 | 36.000 | 62.900 | 190.000 | 50.000 | 89.000 | 195.000 | 40.000 | 92.000 |
| Sodium | | | | | | | | | | | | |
| Magnesium | 32.500 | 7.000 | 15.708 | 21.500 | 10.000 | 15.525 | 44.000 | 8.500 | 28.941 | 56.000 | 23.500 | 38.208 |
| Silica | 39.200 | 26.100 | 35.482 | 16.800 | 14.700 | 15.374 | 28.200 | 15.000 | 19.957 | 32.800 | 15.700 | 22.157 |
| Iron | 0.160 | 0.000 | 0.048 | 0.080 | 0.000 | 0.026 | 0.730 | 0.010 | 0.098 | 0.190 | 0.010 | 0.089 |
| Carbonate (2P) | 36.000 | 4.000 | 15.333 | 32.000 | 0.000 | 8.167 | 36.000 | 4.000 | 8.000 | 40.000 | 0.000 | 16.333 |
| Bicarbonate (T-2P) | 248.000 | 135.000 | 186.250 | 274.000 | 165.000 | 223.250 | 272.000 | 180.000 | 243.000 | 324.000 | 200.000 | 262.583 |
| Chloride | 420.000 | 110.000 | 154.583 | 163.000 | 95.000 | 122.167 | 520.000 | 145.000 | 312.917 | 575.000 | 285.000 | 381.917 |
| Sulfate | 348.000 | 10.500 | 45.500 | 30.500 | 7.500 | 16.399 | 985.000 | 57.000 | 220.792 | 740.000 | 101.000 | 269.792 |
| Ammonia | 1.250 | 0.000 | 0.553 | 1.010 | 0.000 | 0.277 | 5.300 | 0.180 | 1.002 | 1.620 | 0.170 | 0.816 |
| Nitrite | 0.026 | 0.000 | 0.005 | 0.005 | 0.000 | 0.000 | 0.030 | 0.000 | 0.004 | 0.026 | 0.000 | 0.005 |
| Nitrate | 1.335 | 0.050 | 0.534 | 1.100 | 0.040 | 0.341 | 2.500 | 0.030 | 0.300 | 0.800 | 0.060 | 0.294 |
| $PO_4$ Total | 0.790 | 0.220 | 0.458 | 0.660 | 0.040 | 0.192 | 2.100 | 0.160 | 0.538 | 0.660 | 0.100 | 0.319 |
| $PO_4$ Ortho | 0.790 | 0.060 | 0.372 | 0.610 | 0.010 | 0.140 | 1.650 | 0.090 | 0.392 | 0.350 | 0.040 | 0.218 |
| Hardness | 652.000 | 243.000 | 331.083 | 314.000 | 242.000 | 266.000 | 704.000 | 290.000 | 486.167 | 796.000 | 398.000 | 534.500 |
| pH | 8.500 | 7.400 | 8.026 | 8.200 | 7.600 | 7.898 | 8.200 | 7.500 | 7.926 | 8.600 | 7.800 | 8.126 |
| Specific Conduct. | 1726.000 | 555.000 | 747.364 | 913.000 | 572.000 | 684.273 | 1957.000 | 821.000 | 1294.818 | 2431.000 | 1147.000 | 1700.909 |
| Turbidity | 670.000 | 10.000 | 125.000 | 998.000 | 4.000 | 93.769 | 343.000 | 10.000 | 71.077 | 500.000 | 31.000 | 109.769 |

C. FISH

Numerical and dry weight standing crops of all fish collected during the study period are given in Table 3. Estimates of annual production for *Rhinichthys osculus* at each station are given in Table 4. Greatest production occurred at station 1 and least at station 2. In spite of the wide range of values, turnover (P/B) ratios were remarkably similar at all stations.

Table 3. Number and mg dry weight (in parentheses) of fish per square meter in Deep Creek, Idaho-Utah.

| | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 1970 July-August | | | | |
| *Rhinichthys osculus* | .736(340) | .138(38) | 1.872(381) | .838(305) |
| *Perca flavescens* | | .046 | | |
| *Micropterus salmoides* | | .021 | | |
| December | | | | |
| *Rhinichthys osculus* | .029(34) | .010(5) | .303(104) | .424(176) |
| *Micropterus salmoides* | | .004 | | |
| *Cyprinus carpio* | | .004 | | |
| 1971 March | Flood -- no samples taken | | | |
| May | | | | |
| *Rhinichthys osculus* | .864(515) | .004(3) | .255(79) | 0(0) |
| *Gila atraria* | | | .003 | |
| August | | | | |
| *Rhinichthys osculus* | .104(54)* | 1.225(440) | .117(45)** | .167(88) |
| *Cyprinus carpio* | | .092 | | |
| *Perca flavescens* | | .021 | | |

* Population appears to have been reduced by flood 2 weeks earlier.
** Dense macrophyte growth impeded collection of fish.

Table 4. Annual production (dry weight) of *Rhinichthys osculus* based on collections from August 1970 through May 1971*.

| Station | P | P/B |
|---|---|---|
| 1 | .95 $g/m^2$ | 3.21 |
| 2 | .06 | 3.76 |
| 3 | .61 | 3.24 |
| 4 | .51 | 3.20 |

*Recruitment via reproduction begins in June.

## D. BENTHOS

Since the last progress report, 48 new additions have been made to the aquatic invertebrate species list for Deep Creek (Table 5) including 26 Diptera from a list provided by G. F. Knowlton (Utah State Univ., Ecol. Ctr. Terr. Arthropod Ser. No. 3). Twelve species names have been added or changed, including 3 range extensions. This brings the total number of known taxa to 99 insects and 20 other invertebrates. However, as will be seen, only a few of these are important in terms of numbers or biomass. Among the authorities responsible for species determinations are Dr. H. P. Brown, Univ. Oklahoma (Elmidae); Dr. D. G. Denning, Moraga, California (Trichoptera); Dr. J. D. Haddock, St. Olaf College (*Leptocella*); Dr. H. B. Leech, Calif. Acad. Sci. (Coleoptera); U.S. Dept. Agric., Insect Ident. Branch, Beltsville, Maryland (Decapoda, Diptera, Hemiptera); Dr. M. J. Westfall, Jr., Univ. Florida (Odonata); and Dr. G. Wiggins, Royal Ontario Museum (Trichoptera).

Table 5. Addendum to the invertebrate species list for Deep Creek, Curlew Valley, Idaho-Utah, through February, 1971. Letters in parentheses indicate: new additions to the list (a), species name addition or change (b), and range extension (c).

| Organisms | Station 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Mollusca | | | | |
| Lymnaeidae | | | | |
| *Radix auricularia* (a) | | | x | |
| Annelida | | | | |
| Hirudinea | | | | |
| Glossiphoniidae | | | | |
| *Glossiphonia* sp. (a) | | | x | |
| Arthropoda | | | | |
| Decapoda | | | | |
| Palaemonidae | | | | |
| *Pacifastacus gambelli gambelli* (Girard) (b,c) | | x | x | |

Table 5. continued

| Organisms | Station 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Ephemeroptera | | | | |
| Caenidae | | | | |
| *Caenis simulans* McDunnough (a) | | | x | |
| Baetidae | | | | |
| *Callibaetis nigritus* Banks (b) | | | x | x |
| *Centroptilum* (prob. *selanderorum*) Edmunds (b) | | | x | |
| Ephemerellidae | | | | |
| *Ephemerella* sp. (a) | x | | | |
| Odonata | | | | |
| Libellulidae | | | | |
| *Sympetrum danae* (Sulz.) (a) | | | x | |
| *S. obtrusum* (Hag.) (a) | | | x | |
| *S. occidentale* Bart. (a) | | | x | |
| Hemiptera | | | | |
| Corixidae | | | | |
| *Hesperocorixa laevigata* (Uhler) (a) | | | | x |
| *Sigara nevadensis* (Walley) (b,c) | ? | ? | ? | x |
| Gerridae | | | | |
| *Gerris remigis* Say (b) | x | x | x | |
| Notonectidae | | | | |
| *Notonecta kirbyi* Hung. (b) | x | | | |
| Megaloptera | | | | |
| Sialidae | | | | |
| *Sialis* sp. (a) | | | x | |
| Coleoptera | | | | |
| Dytiscidae | | | | |
| *Agabus intersectus* (Crotch) (b) | x | | | x |
| *Deronectes striatellus* (LeConte) (b,c) | x | x | | |
| *Laccophilus maculosa decipiens* LeConte (a) | x | x | | |
| Other | x | x | x | x |
| Elmidae | | | | |
| *Dubiraphia guilianii* VanD. (b) | x | x | x | x |
| *Optioservus divergens* LeConte (b) | x | x | x | x |
| *O. bimaculatus* (a) | | x | x | |
| *O. seriatus* (a) | | | x | |
| *Stenelmis* sp. (a) | | | | x |
| Gyrinidae | | | | |
| *Gyrinus* sp. (a) | x | | x | |
| Haliplidae | | | | |
| *Haliplus immaculicollis* Harris (a) | x | x | x | |
| Trichoptera | | | | |
| Brachycentridae | | | | |
| *Brachycentrus* sp. (a) | | | x | |
| Hydropsychidae | | | | |
| *Hydropsyche californica* Banks (a) | | x | | |
| Leptoceridae | | | | |
| *Leptocella diarina* (b,c) | x | x | x | x |
| Limnephilidae | | | | |
| *Limnephilus frijole* Ross (b) | | x | | |

Table 5. continued

| Organisms | Station 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Diptera | | | | |
| Ceratopogonidae | | | | |
| *Palpomyia or Bezzia* sp. (a) | x | x | x | x |
| Chironomidae | | | | |
| *Diamesa* sp. (a) | x | x | x | x |
| Other | | | | |
| Dolichopodidae | | | | |
| *Diaphorus aldrichi* Van D. (a) | Curlew Reservoir (Adult) | | | |
| *D. palpiger* Whl. (a) | Curlew Reservoir (Adult | | | |
| *Dolichopus acuminatus* Lw. (a) | Stone, Idaho (Adult) | | | |
| *D. adaequatus* Van D. (a) | Snowville, Utah (Adult) | | | |
| *D. bifractus* Lw. (a) | Curlew Reservoir (Adult) | | | |
| *D. conspectus* Van D. (a) | " " (Adult) | | | |
| *D. idahoensis* (Ald.) (a) | " " (Adult) | | | |
| *D. jugalis* Tuck. (a) | " " (Adult) | | | |
| *D. obcordatus* Ald. (a) | " " (Adult) | | | |
| *D. plumipes* (Scop.) (a) | " " (Adult) | | | |
| *D. ramifer* Lw. (a) | " " (Adult) | | | |
| *Pelastoneurus vagans* Lw. (a) | Snowville, Utah (Adult) | | | |
| *Scellus exustus* (Wlk.) (a) | Curlew Reservoir (Adult) | | | |
| *Sympycnus* sp. (a) | Curlew Reservoir (Adult) | | | |
| *Syntormon* sp. (a) | Snowville, Utah (Adult) | | | |
| *Thrypticus fraterculus* (Whyl.) (a) | Snowville, Utah (Adult) | | | |
| Ephydridae | | | | |
| *Hydrellia* sp. (a) | | | | x |
| Psychodidae | | | | |
| *Pericoma* sp. (a) | x | | | |
| Simuliidae | | | | |
| *Simulium argus* Will (b) | x | x | x | x |
| *S. vittatum* Zett. (a) | Curlew Reservoir (Adult) | | | |
| Stratiomyiidae | | | | |
| *Hedriodiscus truquii* (Bellardi) (a) | Snowville, Utah (Adult) | | | |
| *Nemotelus canadensis* Lw. (a) | Curlew Reservoir (Adult) | | | |
| *N. communis* Hanson (a) | Snowville, Utah (Adult) | | | |
| *N. jamesi* Hanson (a) | Curlew Reservoir (Adult) | | | |
| *N. nigrinus* Fallen (a) | " " (Adult) | | | |
| *N. politus* Hanson (a) | " " (Adult) | | | |
| *Odontomyia pubescens* Day (a) | Stone, Idaho (Adult) | | | |
| Tabanidae | | | | |
| *Chrysops mitis* O. S. (a) | Snowville, Utah (Adult) | | | |
| *Tabanus stonei* Philip (a) | Snowville, Utah (Adult) | | | |

1. Species and numbers

Table 6 gives a synopsis of the benthos numerical data from station 1 and the data is illustrated in Figures 6 and 7. In the riffle areas the total number of organisms per month showed a general decrease throughout the winter reaching very low densities in April and May. This was followed by increasing numbers until August when the greatest density of the study period was obtained (110,276), which is almost half of the total number captured during the 11-month period (265,532). The mean number per sample was 24,139 organisms/m$^2$. Figure 6 shows the range of the two samples taken each month and except in three cases the range was very low. In the reach areas of station 1 the greatest density was reached in January, followed by a rapid decrease to the lowest levels in April, followed in turn by a gradual increase (Fig. 7). The range between samples generally was low. The mean sample size was 7,572, about one-third the size of riffle samples. The mean number of organisms captured for the entire station was 15,856/$m^2$. Chironomidae larva predominated in both riffle and reach sections, comprising 56% of the total fauna in both areas (Table 7). *Hyalella azteca* made up over 20% of the fauna in both regions.

Table 6. Mean number and range of benthic invertebrates per square meter at station 1, Deep Creek, Curlew Valley.

| | Riffle (A-B) | | Reach (C-D) | |
|---|---|---|---|---|
| Month | Mean | Range | Mean | Range |
| Sept. 1970 | --- | --- | --- | --- |
| Oct. | 20,048 | 28,336 - 11,760 | 3,888 | 4,160 - 3,616 |
| Nov. | 48,128 | 76,368 - 19,888 | 7,056 | 9,376 - 4,736 |
| Dec. | 13,000 | 18,544 - 7,456 | 8,560 | 15,952 - 1,168 |
| Jan. 1971 | 18,520 | 20,304 - 16,736 | 22,032 | 30,768 - 13,296 |
| Feb. | 4,408 | 6,064 - 2,752 | 11,952 | 18,848 - 5,056 |
| March | 39,552 | 70,928 - 8,176 | 888 | 1,136 - 640 |
| April | 176 | 208 - 144 | 192 | 208 - 176 |
| May | 264 | 336 - 192 | 240 | 304 - 176 |
| June | 3,744 | 5,168 - 2,320 | 9,368 | 14,656 - 4,080 |
| July | 7,416 | 7,424 - 7,408 | 5,760 | 6,944 - 4,576 |
| Aug. | 110,276 | 182,936 - 37,616 | 13,360 | 17,872 - 8,848 |
| Total | 265,532 | 182,936 - 144 | 83,296 | 30,768 - 176 |
| $\bar{x}$ = | 24,139 | | 7,572 | |
| $\bar{x}$ of entire sta. = 15,856 | | | | |

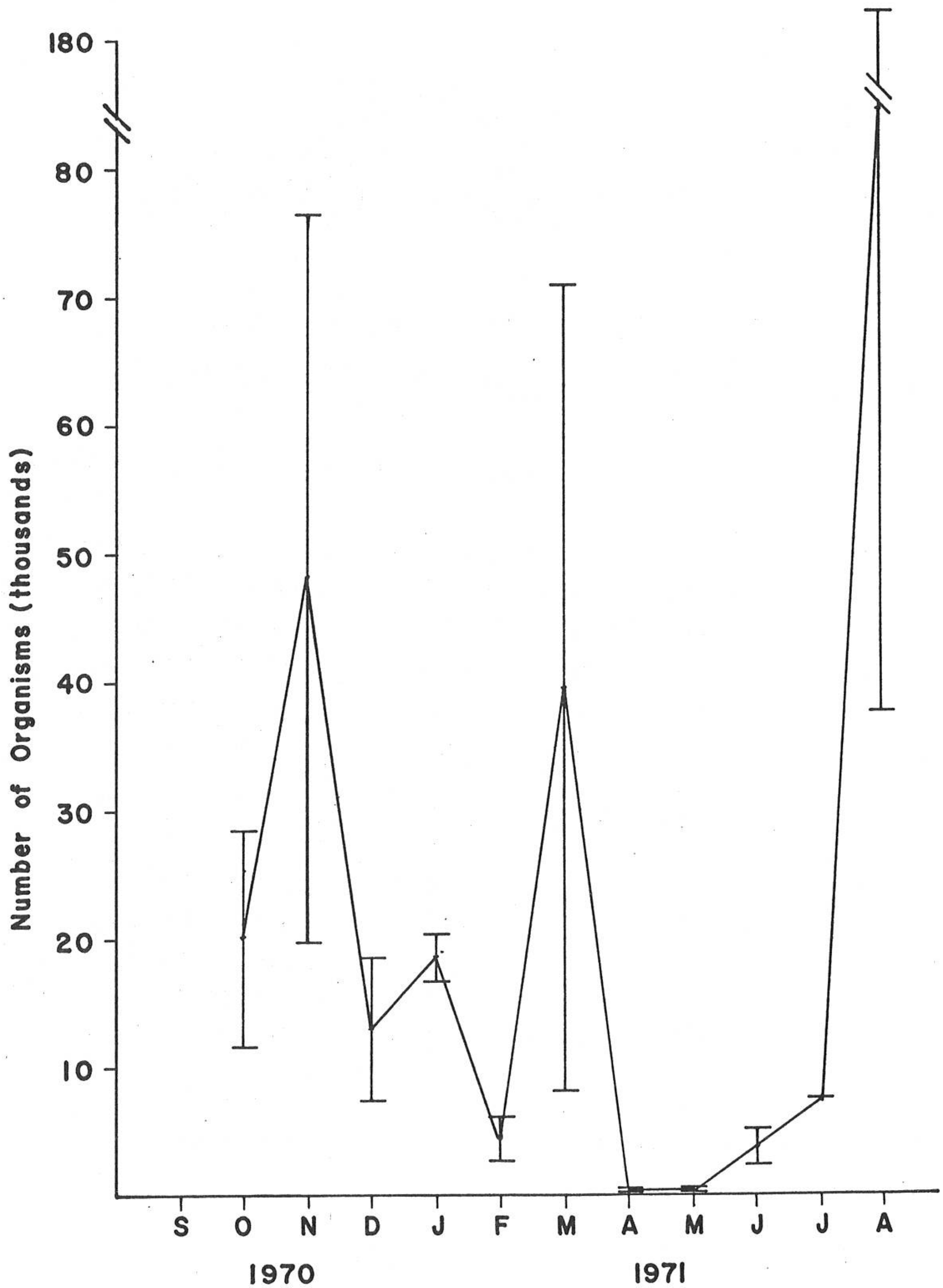


Figure 6. Range and mean of the number of organisms per square meter collected each month from station 1, riffle areas, Deep Creek, Curlew Valley.

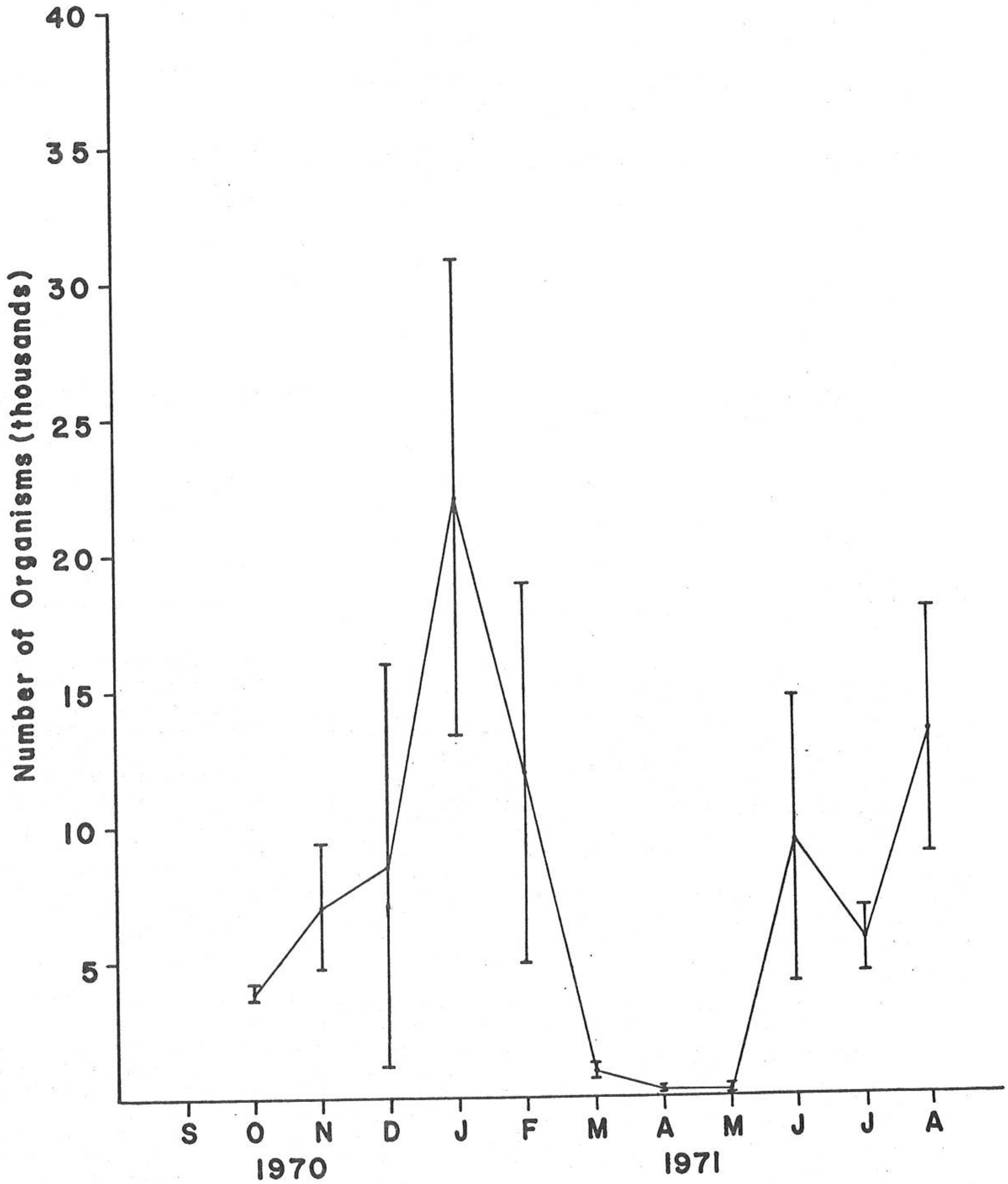


Figure 7. Range and mean of the numbers of organisms per square meter collected each month from station 1, reach areas, Deep Creek, Curlew Valley.

Table 7. Organisms with densities greater than 5000/m$^2$ and the three most abundant Orders for the period October, 1970, through August, 1971, at station 1, Deep Creek, Curlew Valley.

| | Riffle (A-B) | | Reach (C-D) | |
|---|---|---|---|---|
| Predominant Organisms | No./m$^2$ | % of Total | No./m$^2$ | % of Total |
| Chironomidae | 163,000 | 56.2 | 34,472 | 56.0 |
| *Hyalella azteca* | 84,168 | 29.0 | 13,696 | 22.2 |
| *Simulium* sp. | 14,464 | 5.0 | 7,296 | 11.8 |
| *Baetis tricaudatus* | 11,146 | 3.8 | 4,272 | 6.9 |
| 3 Predominant Orders | No./m$^2$ | % of Total | No./m$^2$ | % of Total |
| Diptera | 179,032 | 61.7 | 39,496 | 64.1 |
| Amphipoda | 84,168 | 29.0 | 13,696 | 22.2 |
| Ephemeroptera | 11,186 | 3.9 | | |
| Mollusca | | | 2,328 | 3.8 |

Changes in density in both riffle and reach areas at station 2 were similar to the changes evident at station 1. Beginning in October the number of organisms captured each month decreased until April, when the lowest densities were obtained. From April on, the values showed a slight increase, but the high densities found prior to April were never approached (Table 8). Figures 8 and 9 show a drastic decrease in numbers from March to April, probably due to the flood that occurred between these sampling periods. Densities in the riffle and pool were comparable, with riffle areas totaling 188,598 organisms collected (mean 17,145) and reach areas totaling 115,616 organisms (mean 10,511). The riffle samples were very close numerically. The reach areas were not as similar; in two cases the variation between samples was considerable. The riffle samples were dominated by three species of *Optioservus*, comprising 27% of the total fauna, while *Hyalella azteca* and *Tricorythodes minutus* made up 21.6% and 13.5% respectively (Table 9). These three groups also dominated the reach areas but in a different sequence. *Hyalella azteca* comprised 38.3% of the reach fauna, *Tricorythodes minutus* 29.2% and *Optioservus* 15.4%.

At station 3 the total number of organisms collected (250,660) was second only to station 1. The trend in monthly densities is similar to stations 1 and 2 beginning with initial high densities, decreasing rapidly, reaching the lowest densities in January instead of April, and then followed by a general increase in numbers. The mean number of organisms collected each month was 22,787 (Table 10). The two samples taken each month showed very little variation in numbers, due perhaps to the uniform nature of the substratum and flow at this station (Fig. 10). *Hyalella azteca* again was the most abundant organism captured (Table 11), comprising almost half (43.9%) of all organisms collected. The Chironomidae and *Dubiraphia guilianii* were distant seconds in abundance, both comprising 13.6% of the total fauna.

Table 8. Mean number and range of benthic invertebrates per square meter at station 2, Deep Creek, Curlew Valley.

| | (Riffle (A-B) | | Reach (C-D) | |
|---|---|---|---|---|
| Month | Mean | Range | Mean | Range |
| Sept. 1970 | --- | --- | --- | --- |
| Oct. | 58,864 | 68,272 - 49,456 | 23,816 | 26,448 - 21,184 |
| Nov. | 8,264 | 12,784 - 3,744 | 32,824 | 43,392 - 22,256 |
| Dec. | 25,608 | 26,080 - 25,136 | 17,216 | 19,776 - 14,656 |
| Jan. 1971 | 19,768 | 23,168 - 16,368 | 656 | 1,216 - 96 |
| Feb. | 25,894 | 27,056 - 24,432 | 19,320 | 33,168 - 5,472 |
| March | 20,360 | 28,528 - 12,192 | 3,152 | 4,352 - 1,952 |
| April | 3,248 | 4,304 - 2,192 | 336 | 400 - 272 |
| May | 8,096 | 9,248 - 6,944 | 1,752 | 3,200 304 |
| June | 5,016 | 5,312 - 4,720 | 6,864 | 8,448 - 5,280 |
| July | 3,680 | 6,736 - 624 | 7,240 | 9,568 4,912 |
| Aug. | 9,800 | 18,528 - 1,072 | 2,440 | 4,400 - 480 |
| Total | 188,598 | 68,272 - 624 | 115,616 | 43,392 - 96 |
| $\bar{x}$ = | 17,145 | | 10,511 | |

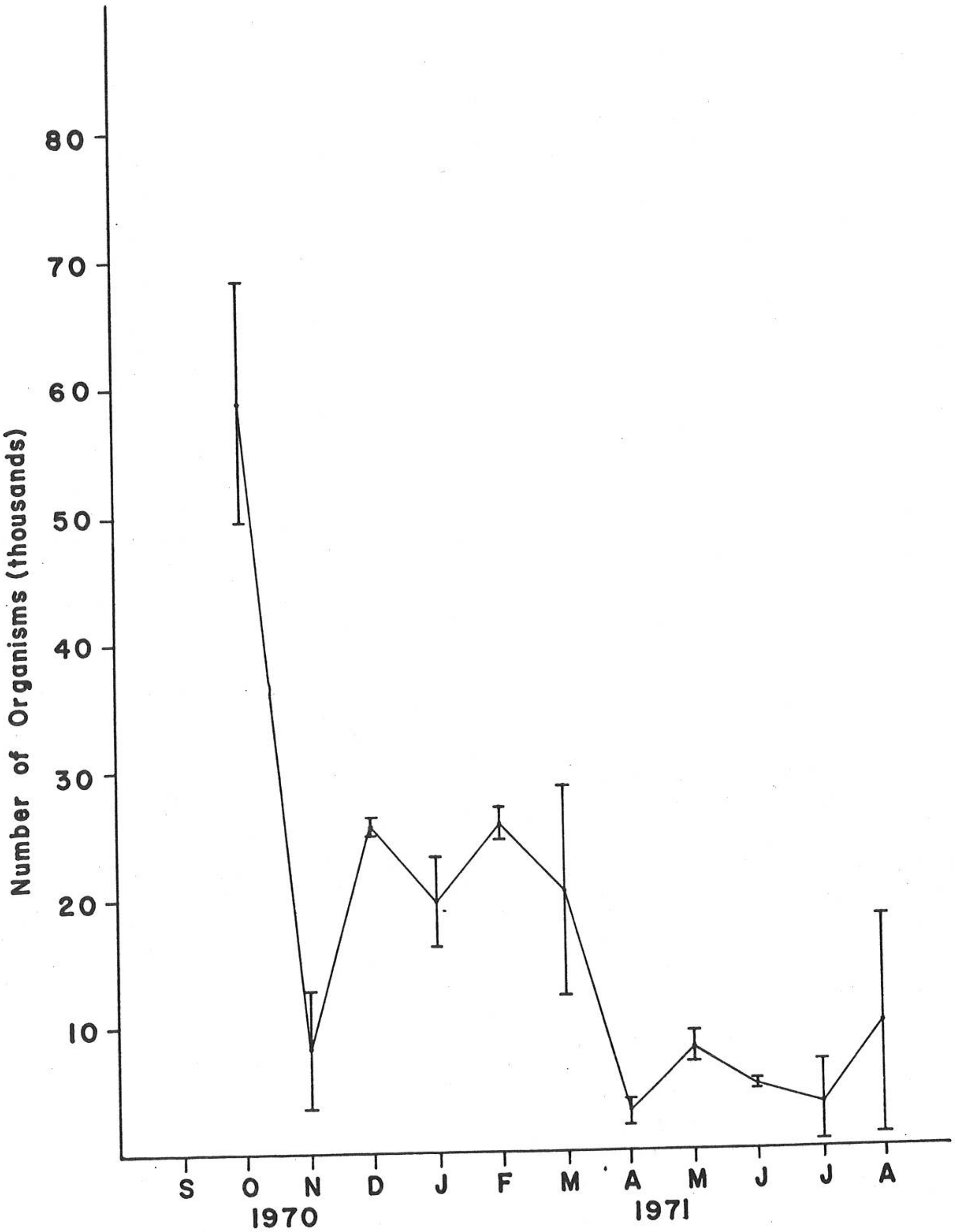


Figure 8. Range and mean of the number of organisms per square meter collected each month from station 2 riffle areas, Deep Creek, Curlew Valley.

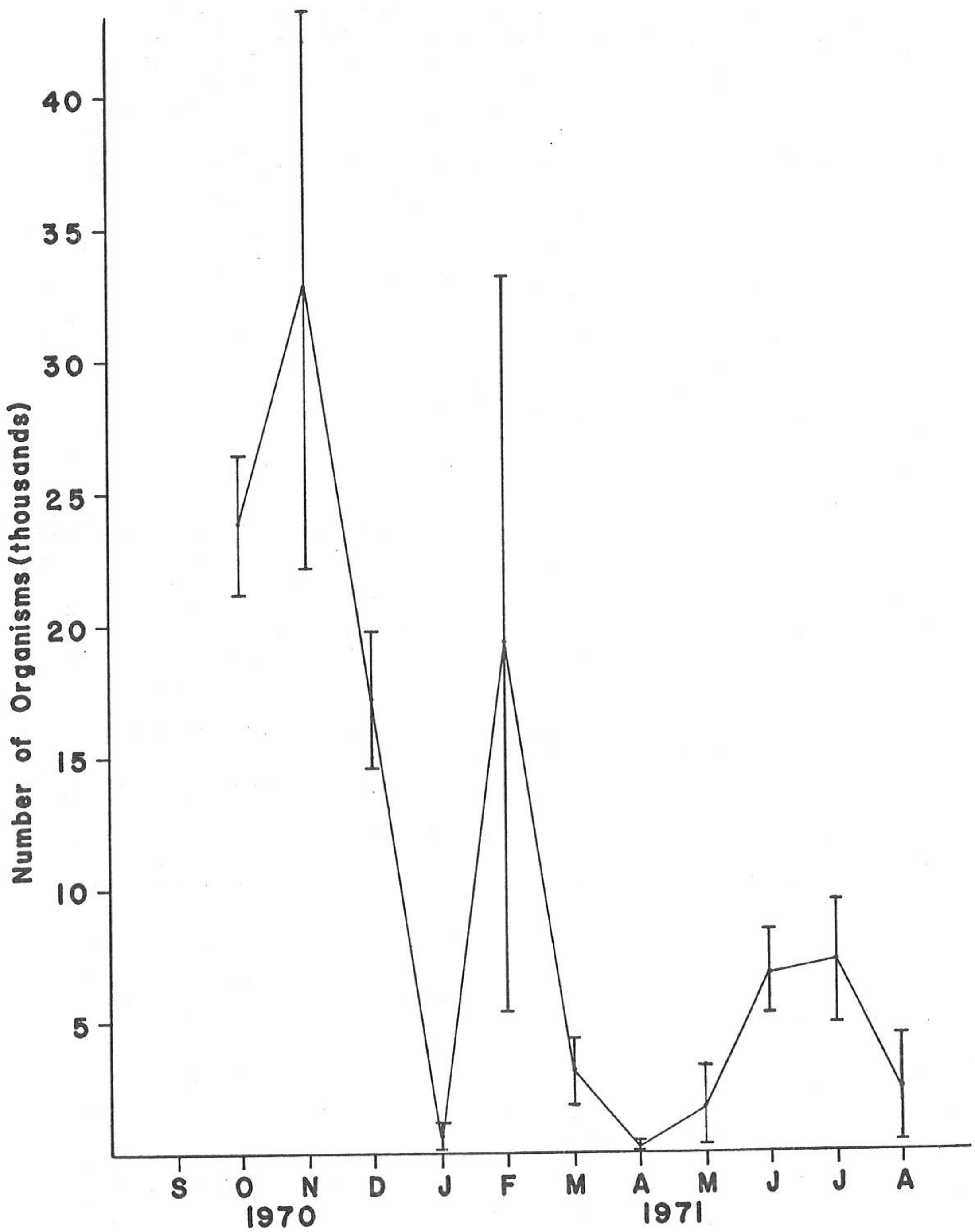


Figure 9. Range and mean of the number of organisms per square meter collected each month from station 2 reach areas, Deep Creek, Curlew Valley.

Table 9. Organisms with densities greater than 5000/$m^2$ and the three most abundant Orders for the period October, 1970, through August, 1971.

| | Riffle (A-B) | | Reach (C-D) | |
|---|---|---|---|---|
| Predominant Organisms | No./$m^2$ | % of Total | No./$m^2$ | % of Total |
| *Optioservus* spp. | 50,548 | 27.0 | 17,760 | 15.4 |
| *Hyalella azteca* | 40,349 | 21.6 | 44,320 | 38.3 |
| *Tricorythodes minutus* | 25,200 | 13.5 | 33,792 | 29.2 |
| Chironomidae | 18.160 | 9.7 | 9,256 | 8.0 |
| *Hydropsyche* sp. | 17,952 | 9.6 | 1,464 | 1.3 |
| *Baetis tricaudatus* | 15,444 | 8.3 | 5,672 | 4.9 |
| *Simulium* spp. | 13,176 | 7.0 | 960 | 0.8 |
| 3 Predominant Orders | No./$m^2$ | % of Total | No./$m^2$ | % of Total |
| Coleoptera | 50,572 | 27.1 | 17,944 | 15.5 |
| Amphipoda | 40,976 | 21.9 | 44,408 | 38.4 |
| Ephemeroptera | 40,640 | 21.7 | 39,464 | 34.1 |

Table 10. Mean number and range of benthic invertebrates per square meter at station 3, Deep Creek, Curlew Valley.

| | Reach (C-D) | |
|---|---|---|
| Month | Mean | Range |
| Sept. 1971 | --- | --- |
| Oct. | 82,336 | 97,392 - 67,280 |
| Nov. | 42,952 | 46,960 - 38,944 |
| Dec. | 15,688 | 21,456 - 9,920 |
| Jan. 1971 | 2,456 | 3,664 - 1,248 |
| Feb. | 18,224 | 23,328 - 13,120 |
| March | 12,744 | 17,392 - 8,096 |
| April | 12,240 | 13,648 - 10,832 |
| May | 4,144 | 4,336 - 3,952 |
| June | 9,992 | 10,208 - 9,776 |
| July | 11,464 | 17,072 - 5,856 |
| Aug. | 38,420 | 45,864 - 30,976 |
| Total | 250,660 | 97,392 - 1,248 |
| $\bar{x}$ = | 22,787 | |

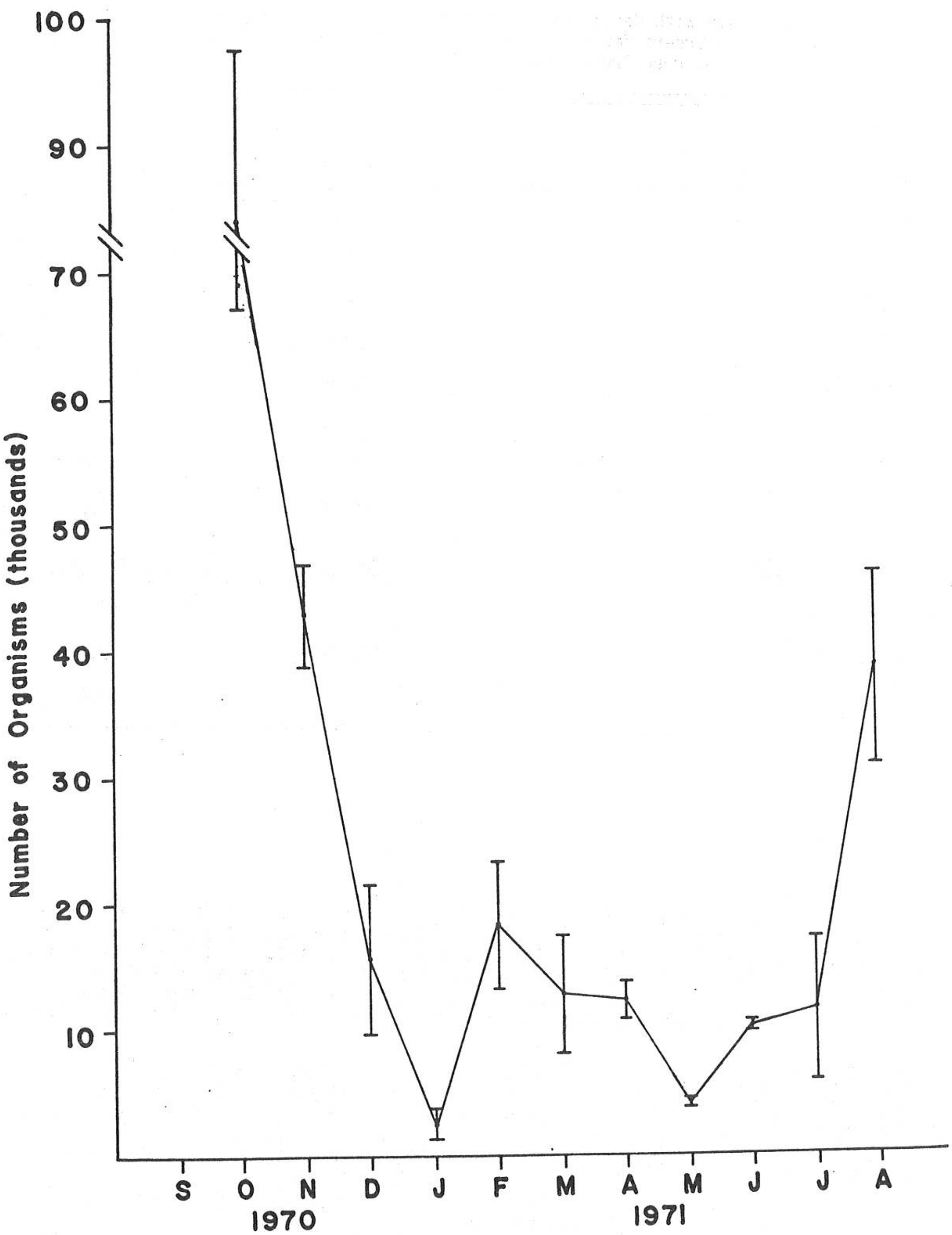


Figure 10. Range and mean of the number of organisms per square meter collected each month from station 3 (reach areas only), Deep Creek, Curlew Valley.

Table 11. Organisms with densities greater than 5000/m² and the three most abundant Orders for the period October, 1970, through August, 1971, at station 3, Deep Creek, Curlew Valley.

| | Reach (C-D) | |
|---|---|---|
| Predominant Organisms | No./$m^2$ | % of Total |
| *Hyalella azteca* | 109,932 | 43.9 |
| Chironomidae | 34,112 | 13.6 |
| *Dubiraphia guilianii* | 34,096 | 13.6 |
| *Bithinia* sp. | 10,464 | 4.2 |
| *Optioservus* sp. | 10,264 | 4.1 |
| *Pisidium* sp. | 10,232 | 4.1 |
| *Enallagma anna* | 9,527 | 3.8 |
| *Gyraulus* sp. | 5,328 | 2.1 |
| 3 Predominant Orders | No./$m^2$ | % of Total |
| Amphipoda | 110,804 | 44.2 |
| Coleoptera | 44,496 | 17.8 |
| Diptera | 35,072 | 14.0 |

Station 4 (Table 12, Fig. 11) differed from the other stations in having low densities in October and November. High densities were attained in December, followed by low densities in March. However, the lowest values were reached in July. The total number of organisms captured during the study period was 138,271 with a mean of 12,570 per month. The number of Chironomidae far outnumbered all other organisms (65.9% of the fauna) while *Hyalella azteca* made up 8.8% and *Simulium* spp. 7.1% of the total (Table 13).

The most abundant group of organisms in Deep Creek are larvae of the family Chironomidae, which totaled 351,952 organisms/$m^2$ or 33.8% of all organisms collected. The taxonomy of the genera and species of this family is not clear at present and thus it is impossible to make any conclusions on life histories. *Hyalella azteca* was the single most abundant invertebrate species collected from Deep Creek (304,905/$m^2$), comprising 29.3% of all organisms. Figure 12 is a length frequency histogram of *Hyalella azteca* from station 3. The lengths given on the vertical axis represent the mean length of each size class, and the number of individuals/$m^2$ are given above each histogram. Smaller individuals dominate the fall and early winter samples but are less important in following months. The lack of individuals in the 1-mm size class from January through July, concurrent with the decrease in abundance of 2-mm individuals, suggests no recruitment of young during this time. The smallest individuals appear again in August and thus reproduction may be occurring in the late summer with juveniles present throughout the winter. These would reach adult stage in the spring. This conclusion is supported by the large percentages of 4-6 mm individuals found during the winter and spring.

Table 12. Mean number and range of benthic invertebrates per square meter at station 4, Deep Creek, Curlew Valley.

| | Reach (C-D) | |
|---|---|---|
| Month | Mean | Range |
| Sept. 1970 | --- | --- |
| Oct. | 4,016 | 4,576 - 3,456 |
| Nov. | 3,936 | 5,920 - 1,952 |
| Dec. | 31,048 | 53,552 - 8,544 |
| Jan. 1971 | 28,128 | 42,304 - 13,952 |
| Feb. | 17,296 | 20,992 - 13,600 |
| March | 3,047 | 4,768 - 1,328 |
| April | 8,112 | 9,632 - 6,592 |
| May | 13,952 | 15,696 - 12,208 |
| June | 7,272 | 10,224 - 4,320 |
| July | 2,064 | 3,184 - 944 |
| Aug. | 19,400 | 35,536 - 3,264 |
| Total | 138,271 | 53,552 - 944 |
| $\bar{x}$ = | 12,570 | |

Table 13. Organisms with densities greater than 5000/m$^2$ and the three most abundant Orders for the period October, 1970, through August, 1971, at station 4, Deep Creek, Curlew Valley.

| | Reach (C-D) | |
|---|---|---|
| Predominant Organisms | No./m$^2$ | % of Total |
| Chironomidae | 92,952 | 65.9 |
| *Hyalella azteca* | 12,440 | 8.8 |
| *Simulium* sp. | 10,072 | 7.1 |
| *Dubiraphia guilianii* | 9,880 | 7.0 |
| *Pisidium* sp. | 5,736 | 4.1 |
| 3 Predominant Orders | No./m$^2$ | % of Total |
| Diptera | 106,632 | 75.7 |
| Coleoptera | 11,280 | 8.0 |
| Amphipoda | 12,440 | 8.8 |

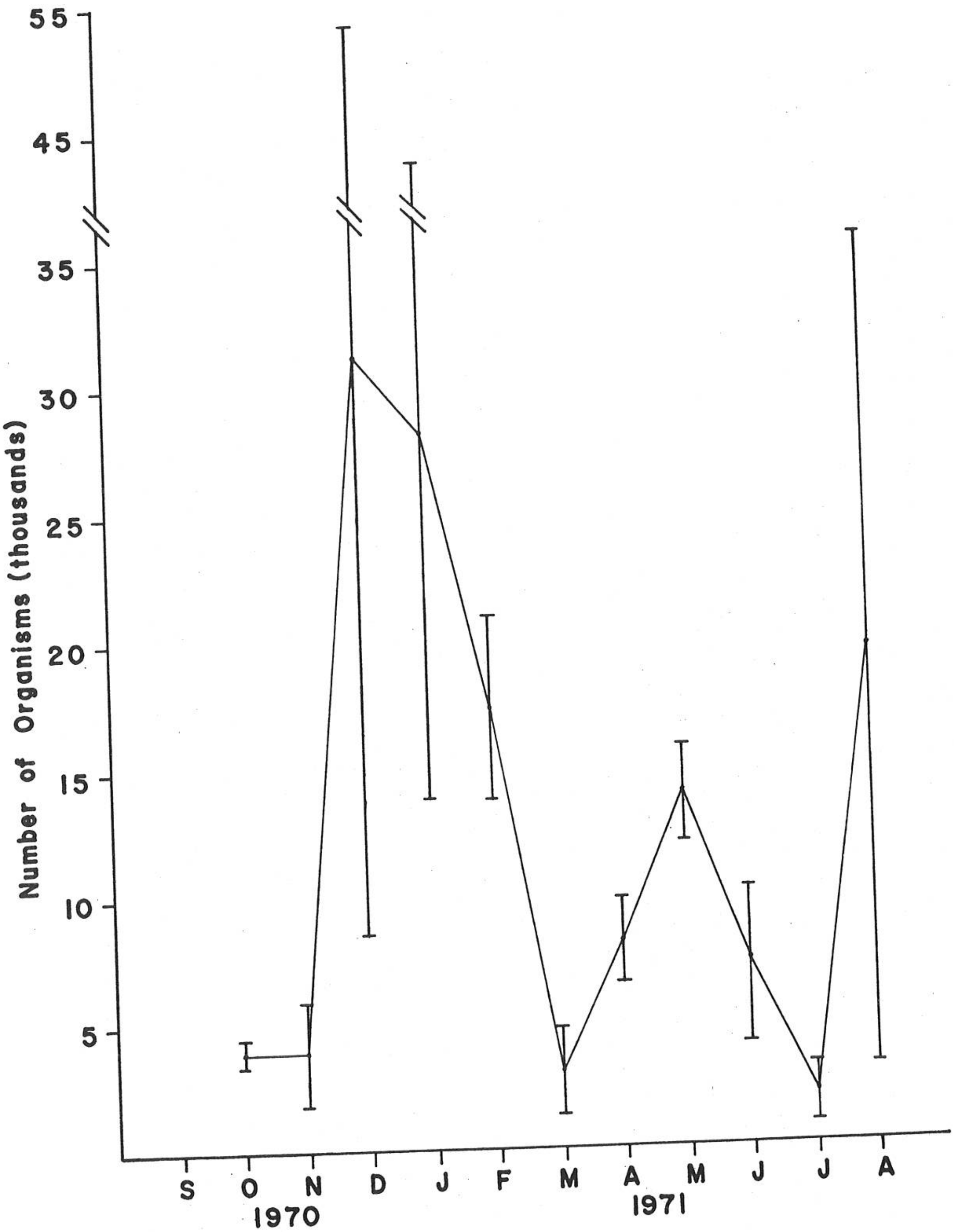


Figure 11. Range and mean of the number of organisms per square meter collected each month from station 4 (reach areas only), Deep Creek, Curlew Valley.

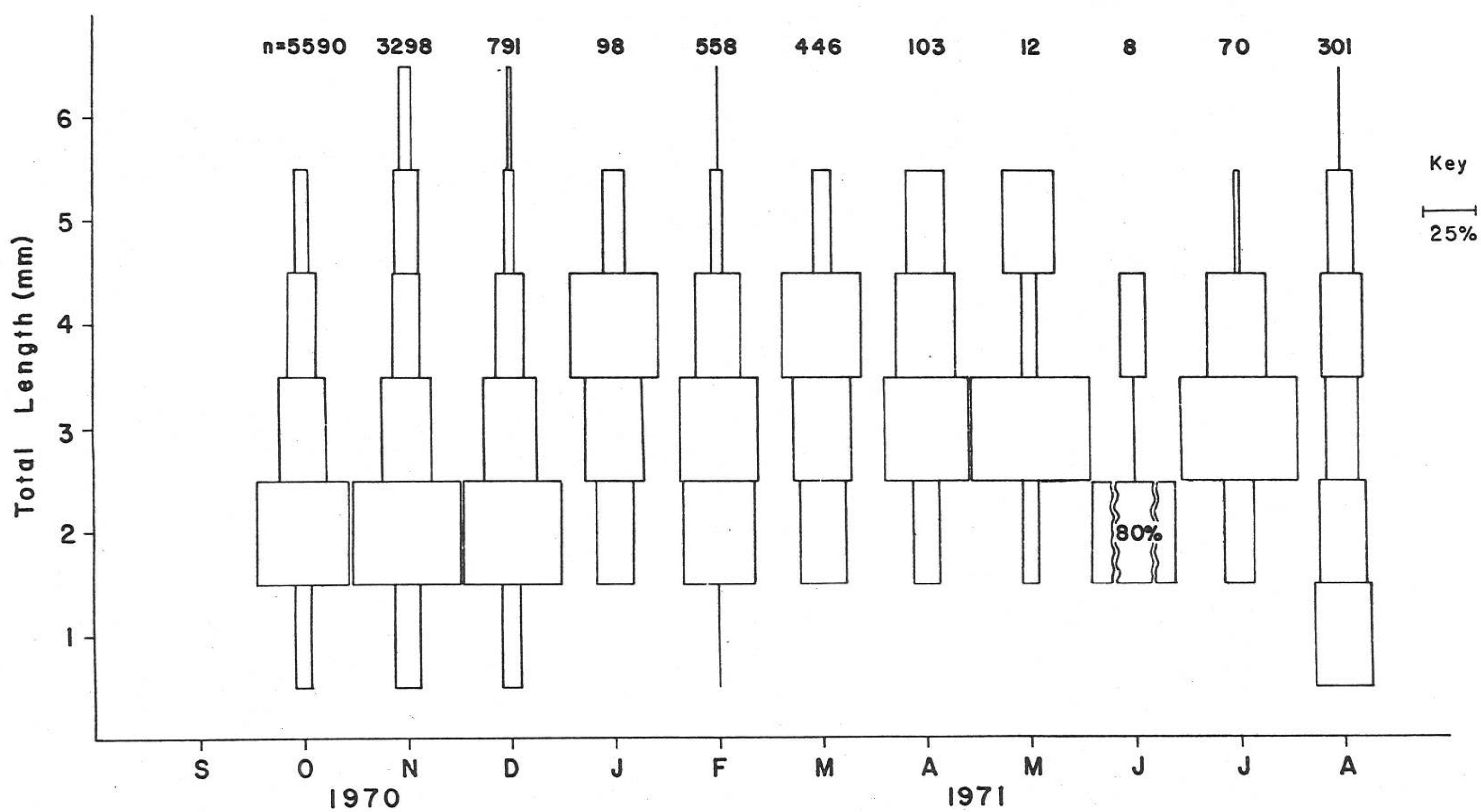


Figure 12. Length-frequency histogram for *Hyalella azteca* from station 3, Deep Creek, Curlew Valley. Lengths given are the mean for each size class. The mean number of *H. azteca* collected each month is given above each histogram.

2. Biomass and production

Benthos production estimates have been made for each site based on monthly collections during the period October, 1970, through August, 1971 (Tables 14-19). The calculations require further checking but even at this preliminary stage the data are useful for comparative purposes. In the following description, collections from riffle and from reach areas are considered to be from separate sites (giving a total of 8 sites).

Greatest production was by *Hyalella azteca* which usually ranked first among the five most productive species at each site. The Chironomidae were next in overall importance although they did not rank among the top five taxa at station 2. Other especially important taxa in regards to production included *Baetis tricaudatus* at station 1 (riffle) and station 2 (reach); *Optioservus divergens* and *Tricorythodes minutus* in both the riffle and reach areas, station 2; *Hydropsyche occidentalis* at station 2 (riffle); *Bithinia* sp., *Pisidium* sp., *Dubiraphia guilianii*, and *Helobdella elongata* at station 3; and *Pisidium* sp. at station 4. In general, the taxa which were most productive in the reaches also were most productive in the riffles but in a different order of importance.

Table 14. Average standing crop, production, and turnover rate of benthic invertebrates (dry weights) at station 1 (sites A and B), Deep Creek, Curlew Valley, October, 1970, through August, 1971.

| Taxon | Av. Standing Crop ($\bar{B}$) ($g/m^2$) | Production (P) ($g/m^2/yr$) | Turnover Rate ($P/\bar{B}$) |
|---|---|---|---|
| *Hyalella azteca* | 4.4491 | 1972.7581 | 443.40 |
| Chironomidae | .8904 | 312.8948 | 351.40 |
| *Baetis tricaudatus* | .4224 | 61.9205 | 146.60 |
| *Simulium* sp. | .2177 | 23.0968 | 106.09 |
| *Hydropsyche occidentalis* | 1.5666 | 10.4990 | 6.70 |
| *Pisidium* sp. | .2006 | 9.0090 | 44.91 |
| Tabanidae | .5123 | 4.3543 | 8.50 |
| *Lymnaea* sp. | .1050 | 3.8763 | 36.90 |
| *Argia vivida* | .3285 | 2.6938 | 8.20 |
| *Enallagma anna* | .5235 | 2.6552 | 5.07 |
| *Hydroptila* sp. | .0263 | 2.4762 | 94.06 |
| *Limnephilus* sp. | .7750 | 1.9910 | 2.57 |
| *Cheumatopsyche analis* | .1601 | 1.8065 | 11.28 |
| *Physa* sp. | .0750 | 1.1576 | 15.44 |
| *Amphiagrion abbreviatum* | .0598 | .8602 | 14.38 |
| *Erpobdella punctata* | .2002 | .7998 | 3.99 |
| *Helobdella elongata* | .1221 | .6715 | 5.50 |
| Hydracarina | .0048 | .4772 | 99.43 |
| Empididae | .0758 | .2424 | 3.20 |
| *Deronectes striatellus* | .0801 | .1542 | 1.92 |

Table 15. Average standing crop, production, and turnover rate of benthic invertebrates (dry weights) at station 1 (sites C and D), Deep Creek, Curlew Valley, October, 1970, through August, 1971.

| Taxon | Av. Standing Crop ($\bar{B}$) ($g/m^2$) | Production (P) ($g/m^2/yr$) | Turnover Rate ($P/\bar{B}$) |
|---|---|---|---|
| Chironomidae | .4995 | 246.9772 | 494.42 |
| *Hyalella azteca* | 1.0375 | 149.3943 | 143.99 |
| *Simulium* sp. | .0750 | 13.3715 | 178.30 |
| *Deronectes striatellus* | .0381 | 11.2477 | 295.15 |
| *Lymnaea* sp. | .0933 | 6.4176 | 68.77 |
| *Argia vivida* | .4684 | 5.8294 | 12.44 |
| *Baetis tricaudatus* | .1163 | 4.1583 | 35.75 |
| *Limnephilus* sp. | .3460 | 3.8167 | 11.03 |
| *Pisidium* sp. | .1212 | 2.5608 | 21.13 |
| *Hydropsyche occidentalis* | .6263 | 2.4298 | 3.88 |
| *Enallagma anna* | .3884 | 1.9401 | 5.00 |
| Hydracarina | .0073 | 1.1491 | 158.00 |
| Empididae | .0453 | .7233 | 15.98 |
| *Erophdella punctata* | .0511 | .5201 | 10.19 |
| *Physa* sp. | .0547 | .5032 | 9.19 |
| *Cheumatopsyche analis* | .0248 | .3337 | 13.43 |
| *Gordius* sp. | .0390 | .3119 | 8.00 |
| Tabanidae | .0687 | .2362 | 3.44 |
| *Sigara* sp. | .0208 | .1664 | 8.00 |

Table 16. Average standing crop, production, and turnover rate of benthic invertebrates (dry weights) at station 2 (sites A and B), Deek Creek, Curlew Valley, October, 1970, through August, 1971.

| Taxon | Av. Standing Crop ($\bar{B}$) ($g/m^2$) | Production (P) ($g/m^2/yr$) | Turnover Rate ($P/\bar{B}$) |
|---|---|---|---|
| *Hyalella azteca* | .9114 | 718.9443 | 788.87 |
| *Optioservus divergens* (larvae) | .3347 | 511.0156 | 1526.83 |
| *Optioservus divergens* (adults) | 1.7092 | 164.0214 | 95.96 |
| *Hydropsyche occidentalis* | 4.4865 | 161.8837 | 36.08 |
| *Tricorythodes minutus* | .5317 | 157.2900 | 295.84 |
| *Simulium* sp. | .3022 | 57.4371 | 190.06 |
| Chironomidae | .3376 | 56.4445 | 167.18 |
| *Baetis tricaudatus* | .3190 | 38.2217 | 119.83 |
| *Pacifastacus gambelli* | 3.7760 | 30.2080 | 8.00 |
| *Argia vivida* | .3564 | 6.2628 | 17.57 |
| *Tinodes* sp. | .2895 | 3.7103 | 12.82 |
| *Pisidium* sp. | .0564 | 3.6232 | 64.28 |
| Empididae | .0397 | 3.0314 | 76.46 |
| *Ophiogomphus severus* | .2743 | 1.8257 | 6.66 |
| *Enallagma anna* | .1483 | 1.1678 | 7.88 |
| *Lanx* sp. | .0179 | .8413 | 47.02 |
| *Physa* sp. | .0708 | .5865 | 8.28 |
| Tabanidae | .0176 | .1408 | 8.00 |
| *Gammarus lacustris* | .1552 | .1198 | .77 |

Table 17. Average standing crop, production, and turnover rate of benthic invertebrates (dry weights) at station 2 (sites C and D), Deep Creek, Curlew Valley, October, 1970, through August, 1971.

| Taxon | Av. Standing Crop ($\bar{B}$) (g/m$^2$) | Production (P) (g/m$^2$/yr) | Turnover Rate (P/$\bar{B}$) |
|---|---|---|---|
| *Hyalella azteca* | 1.4622 | 661.8101 | 452.61 |
| *Tricorythodes minutus* | .8571 | 526.3726 | 614.12 |
| *Optioservus divergens* | .9859 | 76.8576 | 77.95 |
| *Baetis tricaudatus* | .1472 | 69.4802 | 471.87 |
| *Ophiogomphus severus* | .8236 | 18.3676 | 22.30 |
| Chironomidae | .1120 | 8.6636 | 77.36 |
| *Hydropsyche occidentalis* | .3677 | 4.1982 | 11.42 |
| *Pacifastacus gambelli* | .2288 | 1.8304 | 8.00 |
| *Tinodes* sp. | .1141 | 1.6969 | 14.87 |
| *Gammarus lacustris* | .0684 | 1.5348 | 22.45 |
| *Lanx* sp. | .0164 | .7931 | 48.47 |
| *Simulium* sp. | .0156 | .3511 | 22.54 |
| *Argia vivida* | .0224 | .1790 | 7.98 |
| *Bithinia* sp. | .0182 | .1273 | 7.01 |
| *Physa* sp. | .0148 | .1187 | 8.00 |
| *Enallagma anna* | .0134 | .1037 | 7.77 |
| *Pisidium* sp. | .0111 | .1013 | 9.11 |

Table 18. Average standing crop, production, and turnover rate of benthic invertebrates (dry weights) at station 3 (reach only), Deep Creek, Curlew Valley, October, 1970, through August, 1971.

| Taxon | Av. Standing Crop ($\bar{B}$) (g/m$^2$) | Production (P) (g/m$^2$/yr) | Turnover Rate (P/$\bar{B}$) |
|---|---|---|---|
| *Hyalella azteca* | 3.6815 | 3000.9656 | 815.14 |
| *Bithinia* sp. | 13.9304 | 699.8811 | 50.24 |
| *Pisidium* sp. | .8412 | 288.8293 | 343.36 |
| *Dubiraphia guilianii* | 1.2854 | 204.4708 | 159.07 |
| *Helobdella elongata* | 1.5422 | 181.2685 | 117.54 |
| Chironomidae | .0424 | 155.9792 | 367.47 |
| *Gyraulus* sp. | .2349 | 85.5430 | 364.13 |
| *Enallagma anna* | 1.1361 | 67.5100 | 59.42 |
| *Physa* sp. | 1.9258 | 50.5714 | 26.26 |
| *Optioservus divergens* | .5826 | 13.5360 | 23.23 |
| *Hydropsyche occidentalis* | .5257 | 13.1578 | 25.03 |
| *Eropbdella punctata* | 2.3644 | 10.3810 | 4.39 |
| *Gammarus lacustris* | .9044 | 10.0295 | 11.09 |
| *Callibaetis nigritus* | .0102 | 2.9207 | 286.86 |
| *Baetis tricaudatus* | .0452 | 1.5753 | 34.86 |
| *Cheumatopsyche analis* | .0714 | 1.1156 | 15.61 |
| *Lymnaea* sp. | .0595 | .5361 | 9.01 |
| *Glossophonia* sp. | .0524 | .4189 | 8.00 |
| *Sigara* sp. | .0439 | .3514 | 8.00 |
| Hydracarina | .0029 | .1862 | 63.99 |

Table 19. Average standing crop, production, and turnover rate of benthic invertebrates (dry weights at station 4 (reach only), Deep Creek, Curlew Valley, October, 1970, through August, 1971.

| Taxon | Av. Standing Crop ($\bar{B}$) ($g/m^2$) | Production (P) ($g/m^2/yr$) | Turnover Rate ($P/\bar{B}$) |
|---|---|---|---|
| Chironomidae | .5947 | 404.9348 | 680.95 |
| *Pisidium* sp. | .3991 | 69.6369 | 174.47 |
| *Hyalella azteca* | .4029 | 53.5833 | 133.00 |
| *Simulium* sp. | .2000 | 27.0079 | 135.07 |
| *Ophiogomphus severus* | 2.1120 | 9.0800 | 4.30 |
| *Tricorythodes minutus* | .0800 | 3.2550 | 40.71 |
| *Microcylloepus pusillus* | .0378 | .9082 | 24.02 |
| *Enallagma anna* | .1107 | .8561 | 7.74 |
| *Hydropsyche occidentalis* | .0470 | .4399 | 9.36 |
| Dytiscidae | .0223 | .2409 | 10.82 |

The numerically predominant taxa generally were also the most productive, frequently making up for their small size by means of rapid turnover rates. Notable exceptions were *Ophiogomphus* and *Helobdella* which did not rank among the most abundant at any station but which were among the five most productive taxa, at one or more sites. However, in general (for Deep Creek at least) numbers appear to be a reasonable index of production. If correct, the values obtained indicate a much higher production by invertebrates than by fish.

## E. DECOMPOSERS

Rates of microbial activity are summarized in Table 20. Respiration rates were highest at the warmest temperatures (station 2) and in the areas of greatest organic deposition (station 3). All of the respiration values are higher than those recorded for the epilimnion of temperate lakes (approx. .01 g $C/m^2/day$) during peak activity (Kuznetzov, 1959). Rates of mineralization generally were slightly higher in bags on the stream bottom than in those suspended in mid-water. Material in the coarse mesh bags on the stream bed (to which the microfauna had access) averaged 38% greater decomposition than detritus in the fine mesh bags; material in the medium bags was reduced about 5% more than that in the fine mesh bags. Small insects (chironomids) have been observed in all but the fine mesh bags.

## F. ALLOCHTHONOUS MATTER

A major impact of the land on the stream appears to be through the input of allochthonous sediments, organic matter, and nutrients. Although wind-borne and direct-fall sources appear to be relatively minor, wastes from livestock pose a significant source of materials.

Differences in the amounts of plant material reaching the stream at each station (Table 21) reflect differences in the type and amount of riparian vegetation present. Station 1 lies in a steep-sided gully and this appears to prevent much of the wind-borne material from reaching the stream. Station 2 is in a lightly-grazed area of sagebrush and grass, station 3 flows through meadow hayland, and station 4 is overgrown by a dense stand of rose bushes and other woody plants. The low insect biomass at station 4 is of interest but the reason for it is not known. The vegetation could "filter out" the insects before they reach the stream or provide suitable places for clinging and escape.

Table 20. Rates of microbial respiration in the sediments and mean rates of mineralization of plant detritus (October, 1970 - September, 1971).

| | Station 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| | Respiration* (g C/m$^2$/day) | | | |
| June | .08 | -- | .15 | .08 |
| July | .02 | .09 | .09 | .14 |
| August | -- | .14 | .26 | .06 |
| September | .09 | .18 | .17 | .15 |

*Rates measured in February, 1972, were negligible.

| | Mineralization (mg dry weight lost/initial mg/day) | | | |
|---|---|---|---|---|
| Coarse mesh (.5 mm) | | | | |
| Mid-depth | .0082 | .0129 | .0075 | .0076 |
| Bottom | .0083 | .0111 | .0107 | .0090 |
| Medium mesh (.2 mm) | | | | |
| Mid-depth | .0053 | .0089 | .0063 | .0069 |
| Bottom | .0074 | .0098 | .0056 | .0070 |
| Fine mesh (.1 mm) | | | | |
| Mid-depth | .0043 | .0100 | .0053 | .0053 |
| Bottom | .0063 | .0100 | .0058 | .0061 |

Table 21. Wind-borne allochthonous detritus entering Deep Creek during the period of greatest leaf fall, 17 August through 15 November, 1971.

| Station | Ash-free dry weights mg/m$^2$/day | |
|---|---|---|
| | Insects | Plant material |
| 1 | 1.60 | 3.52 |
| 2 | 6.88 | 81.60 |
| 3 | 3.20 | 22.08 |
| 4 | .05 | 132.16 |

It has not been possible to establish rates of inflow from livestock sources or to quantify the amounts involved, but a measure of the problem can be obtained from a census of the overwintering livestock population along Deep Creek (Table 22) and an estimate of manure density. It has been estimated (Kleiber, 1961:263) that a dry cow will consume about 5.27 kg hay per day and produce 1.45 kg feces (dry weights). This means a production of about 2300 kg of manure per day during the winter by cattle alone.

Table 22. Livestock present along Deep Creek, Idaho-Utah, from late autumn to spring, 1971-1972. Census taken 15 February, 1972.

| Location | Feed Lot # | Type: Cattle | Sheep | Horses | Pigs |
|---|---|---|---|---|---|
| Below Station 1 | 1 | 150 | | 8 | |
| Above Station 2 | 2 | 100 | | | |
| | 3 | 100 | | | |
| Below Dam (Road #1) | 4 | 50 | | | |
| | 5 | 20 | 100 | 4 | 8 |
| | 6 | 32 | | 8 | |
| (1/2 of cattle are calves) | 7 | 50 | | | 5 |
| | 8 | 27 | | 3 | |
| | 9 | 100 | | 5 | |
| Across from Station 3 (Road #2) | 10 | 5 | | | |
| Station 3 | 11 | 29 | | | |
| Near School | 12 | 300 | | | |
| | 13 | | | 8 | |
| | 14 | 35 | | | |
| (Road #3) | 15 | | 2000 | | |
| | 16 | 50 | | | |
| | 17 | | | 25 | |
| (Road #4 - State Line) | 18 | 110 | | 6 | |
| | 19 | 22 | | | |
| | 20 | 20 | | 1 | |
| (Road #5 - Weir Road) | 21 | 100 | | | |
| | 22 | 24 | | | |
| | 23 | 31 | | 1 | |
| (dairy cows) | 24 | 35 | | | |
| (Snowville Highway) | 25 | 10 | | 3 | |
| | 26 | 150 | | | |
| | 27 | 80 | | | |
| TOTALS | | 1630 | 2100 | 72 | 13 |

An estimate of the number of fecal deposits produced during the winter of 1971-1972 at station 3 was made from counts taken along two 1m X 100m transects; one taken paralell to and one at right angle to the stream. These produced values of 80 and 162 cowpies respectively. Using an average dry weight of 235 g per cow pie, this is roughly 284 g/m$^2$ within 100 m of the stream for about a 4-month period. During periods of runoff much of this material reaches the stream as solids or leachate, frequently staining the water dark brown.

Table 23. Dissolved and particulate organic carbon (g/m ), Deep Creek, Curlew Valley. Key: * - cattle present upstream; 1. - spring runoff; 2. - low flow, clear water; 3. - dead cow upstream; 4. - turbid water; aquatic plant die off; 5. - turbid water, heavy silt load.

| | 1970 | | | | 1971 | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | S | O | N | D | J | F | M | A | M | J | J | A |
| Station 1 | | | | | | | | | | | | |
| Dissolved | 461.3* | 44.4 | 0.9 | 70.6 | 13.9 | 108.5 | | 144.9[5] | 1.0[2] | 31.1 | 9.8 | 50.9* |
| Particulate | 23.0 | 6.4 | 14.7 | 1.5 | 4.5 | 8.5 | | 1.3 | 2.3 | 0.6 | 5.3 | 0.3 |
| Station 2 | | | | | | | | | | | | |
| Dissolved | 65.8 | 57.7 | 92.7 | 20.2 | 114.0 | 149.7 | | 134.9* | 15.1* | 87.9[3] | 268.2[3] | 25.5 |
| Particulate | 29.7 | 0.5 | 7.3 | 8.1 | 15.7 | 6.4 | | 4.5 | 2.5 | 2.3 | 1.3 | 1.3 |
| Station 3 | | | | | | | | | | | | |
| Dissolved | 263.2[4] | 47.8[4] | 21.0 | 262.1* | 100.2* | 186.2* | | 123.7* | 35.3 | 160.4 | 22.1 | 56.0 |
| Particulate | 26.4 | 2.1 | 4.9 | 9.6 | 8.3 | 8.1 | | 2.0 | 3.3 | 5.7 | 12.9 | 0.5 |
| Station 4 | | | | | | | | | | | | |
| Dissolved | 329.7* | 36.8* | 83.2 | 70.6 | 29.6 | 112.7[5] | | 118.6 | 55.4[2] | 104.4 | 9.8 | 483.4* |
| Particulate | 3.3 | 0.6 | 9.2 | 2.5 | 13.1 | 6.9 | | 3.2 | 3.5 | 2.1 | 13.2 | 0.1 |

High concentrations of organic carbon in the water, especially in the dissolved fraction, commonly were associated with known cattle activity (Table 23). Spring run-off is an important transport mechanism. Organic matter in dissolved form frequently exceeded that in particulate form by at least an order of magnitude. Highest values of dissolved organic carbon were recorded at station 1 (461.3 g/m$^3$) and 4 (483.4 g/m$^3$); somewhat surprisingly the lowest values for any one month commonly were found at station 1 (50% of the time). Particulate organic carbon values remained reasonably constant throughout the period and increases do not seem to be correlated with known physical disturbances. Highest values (all exceeding 20 g/m$^3$) were recorded in September at stations 1 through 3; otherwise the highest values occurred during late fall and winter. A striking exception to this generalization is the high values for stations 3 and 4 in July, which come close to or exceed the concentrations of dissolved organic matter for the same date.

## G. IMPORT-EXPORT

Measurements of water-borne organic matter imported and exported at each station over a 24-hour period were hampered by lack of data on the total volume of water sampled by drift net. The acquisition of additional current meters should alleviate this problem in 1972. One complete set of measurements collected for stations 2 and 3 during April, 1971, (Table 24) indicated a net accumulation of organic matter at station 2 and a net loss at station 3 for that time of the year.

Table 24. Estimates of water-borne import and export of organic matter at stations 2 and 3, Deep Creek, Curlew Valley, 29-30 April, 1971. Caloric content of invertebrates was determined on the basis of the Chironomidae (7010 cal/g) since they comprised 96% of the invertebrate drift by weight; loss-on-ignition of detritus was converted to calories using the equivalent of 5000 cal/g.

| | Imported ($kcal/m^2/day$) | Exported ($kcal/m^2/day$) |
|---|---|---|
| Station 2 | | |
| Noon | | |
| Invertebrates | 133 | 24 |
| Detritus | 2410 | 226 |
| Midnight | | |
| Invertebrates | 76 | 10 |
| Detritus | 965 | 178 |
| Mean | | |
| Invertebrates | 105 | 17 |
| Detritus | 1688 | 202 |
| Station 3 | | |
| Noon | | |
| Detritus | 229 | 364 |
| Midnight | | |
| Detritus | 392 | 320 |
| Mean | | |
| Detritus | 310 | 342 |

## H. PERIPHYTON

Chlorophyll a and organic carbon of the periphyton followed similar trends (Fig. 13). Ice cover and high discharge interferred with the collection of samples at the start of 1971. Some of the major fluctuations were associated with variations in turbidity and discharge (Fig. 4) but many were not. Lowest values at station 1 occurred in the autumn and during spring flood, high values persisted throughout the summer. The patterns for chlorophyll a were similar at stations 1 and 2; variations during the summer occurred at the same time at both stations but were much greater at station 2. At station 3 values increased following the removal of ice cover and remained high through the summer. The summer variations occurred at different times than those at stations 1 and 2 and there was a more consistent upward trend. The autumn-winter values at station 4 were totally different from the other stations but the timing of the summer fluctuations was similar to that at station 3. The major decreases in chlorophyll a during March and June followed highs in turbidity.

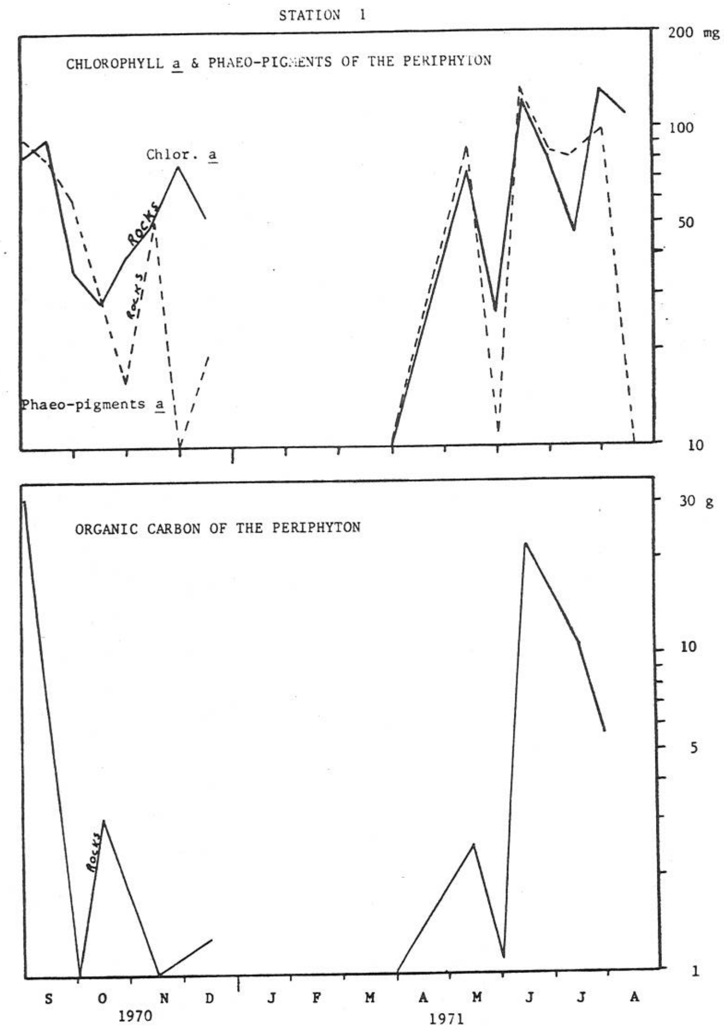


Figure 13A

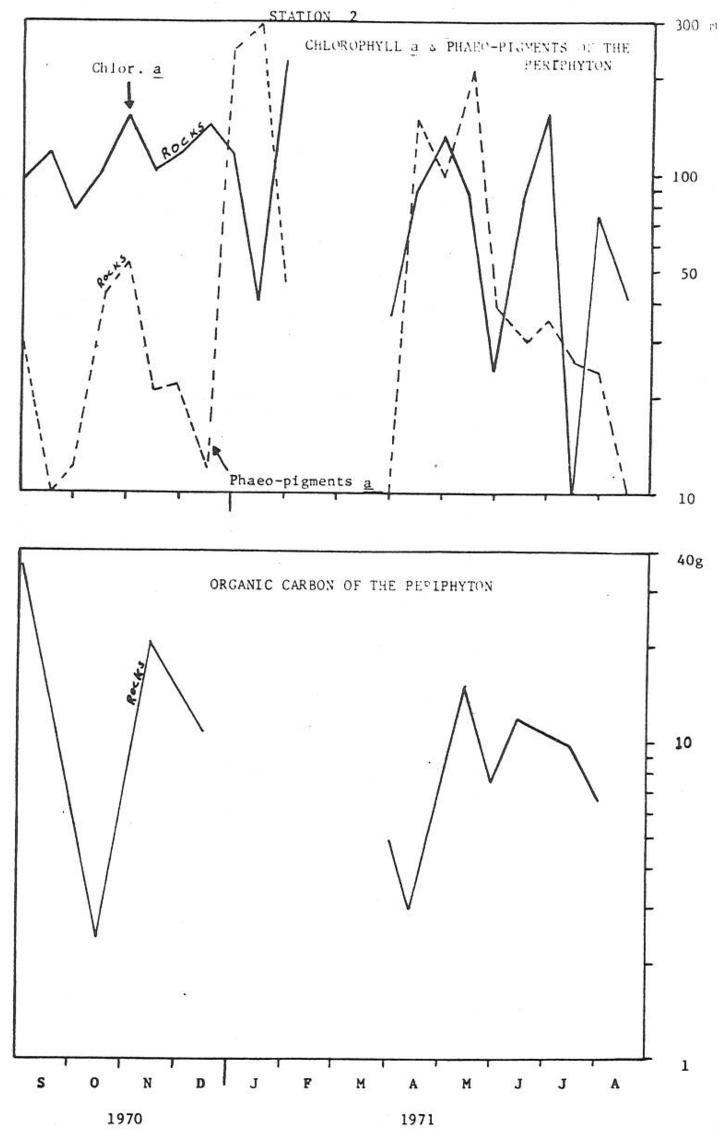


Figure 13B

Figure 13. Chlorophyll a, phaeophytin a, and organic carbon of the periphyton, Deep Creek, Curlew Valley, September, 1970, through August, 1971.

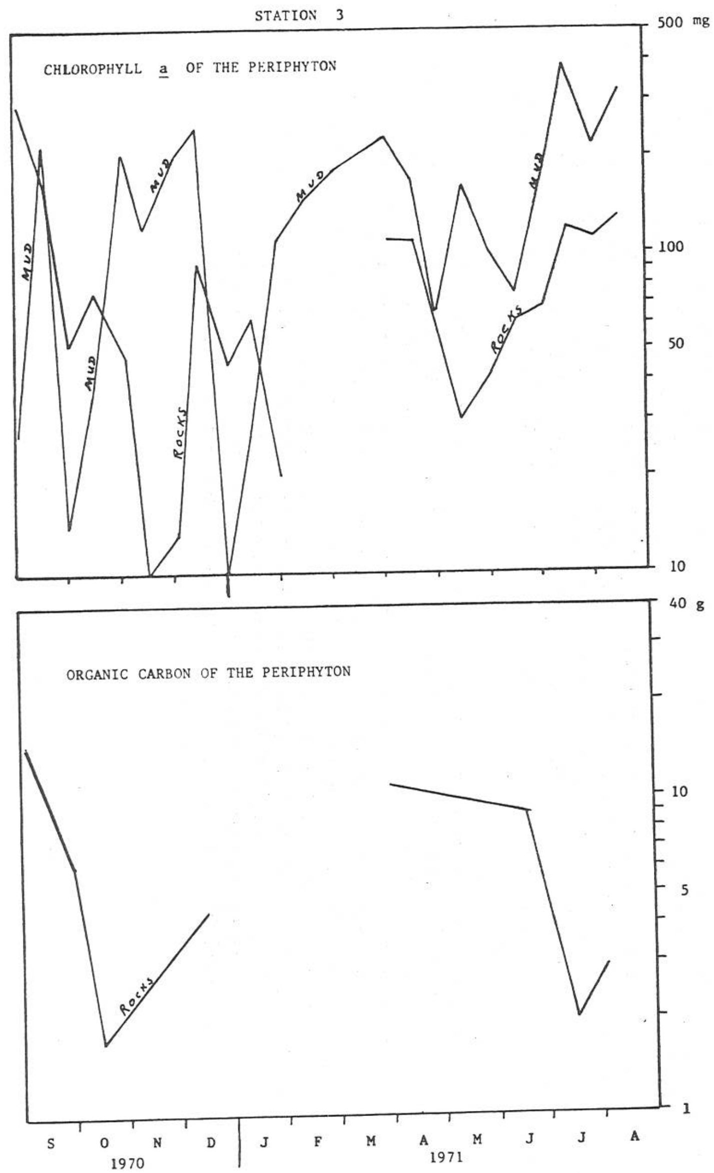


Figure 13C

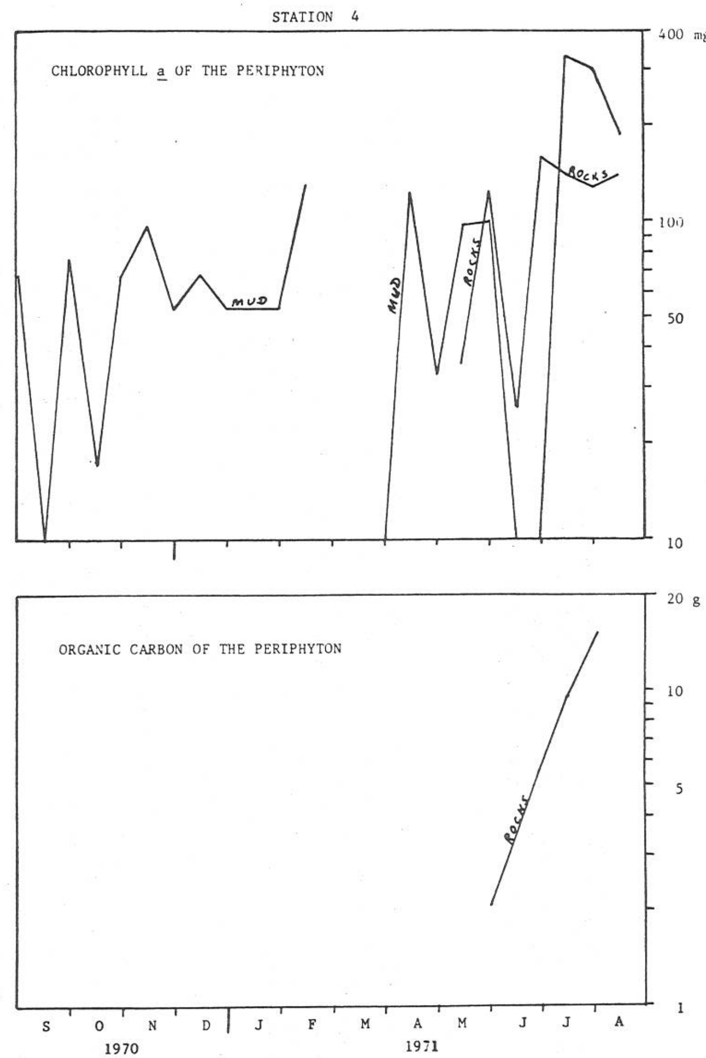


Figure 13D

Figure 13. continued

Phaeophytin concentrations at station 1 followed chlorophyll quite closely. The correspondence was much less at station 2 although the general pattern was the same. Also, the values obtained from the introduced rock substrata followed patterns similar to those of the natural mud substrata although the amounts were not the same.

## I. MACROPHYTES

Macrophyte samples were collected from Deep Creek at monthly intervals as often as weather and water conditions would permit. Samples were collected by hand. Only the portion of the vegetation above the surface of the substratum was removed after it became obvious that rooted portions of the plants commonly formed such a tangled mass as to preclude their complete collection and separation. A Hess sampler having an area of 1/16 $m^2$ was employed to delineate the sampling area. Upon removal the vegetation was transferred to plastic bags, labeled, and returned to the laboratory for separation into species. Individual species comprising the sample were then dried, weighed, and subsequently incinerated to obtain estimates of organic matter.

From observation of the vegetation growing at all of the stations it was obvious that macrophyte production should be separated on the basis of whether growth was occurring in the channel portion of the stream or along the stream edge. It was further apparent that significant differences existed between stations 1 and 2 and stations 3 and 4. Macrophyte biomass attained the highest levels in the upstream stations with biomass levels approaching 400 g/$m^2$ during the peak of the growing season at both the upstream stations. At station 1 (Fig. 14) macrophyte production exceeded 300 g/$m^2$ both along the stream margin and in the channel during the fall of 1970. These high values represented the accumulation of biomass as a result of the summer growing season and declined with the onset of cooler weather and shorter photoperiod in November, 1970. During the winter and spring, samples were obtained only in February and April of 1971 with the other sampling periods being omitted due either to extreme ice conditions or periods of very high flow. Macrophyte growth finally was initiated in 1971 by May 1, and in the first sample interval did not increase significantly (total macrophyte biomass at station 1 along the stream edge less than 10 g/$m^2$). However, the second sample interval of the 1971 growing season saw a dramatic increase in macrophyte production with total macrophyte biomass along the stream edge reaching an excess of 350 g/$m^2$. Although there was an agreement with the U.S. Forest Service that cattle would not be introduced into the area in which station 1 was located, at the time of the August sampling cattle were observed in the area and their effect was dramatically shown in the reduction of macrophyte biomass along the stream margin. Total biomass at this time declined to less than 75 g/$m^2$. Macrophyte production in the channel portion of station 1 did not recover nearly as rapidly as that along the stream margin and total macrophyte biomass did not begin to increase until the August sampling date, at which point a value of approximately 15 g/$m^2$ was obtained.

At station 2 total macrophyte biomass showed an appreciable difference between that in the stream channel and that along the stream margin. Macrophyte production in the channel consisted almost entirely of *Potamogeton filiformis*. Furthermore, in keeping with the nearly stable temperature regime which persists throughout the year, it was observed that macrophyte production along the stream margin peaked during the late fall months and remained at elevated levels in excess of 200 g/$m^2$ until the time of the February sampling. Data from the stream margin at station 2 (Fig. 15) are more erratic than one would anticipate and this factor is related to flucutuating water levels. As a result of water diverted for irrigation, the stream margin frequently was several decimeters away from the stream bank. Hence on some occasions, particularly during the summer of 1971, no vegetation was available for sampling as the littoral zone was completely dry.

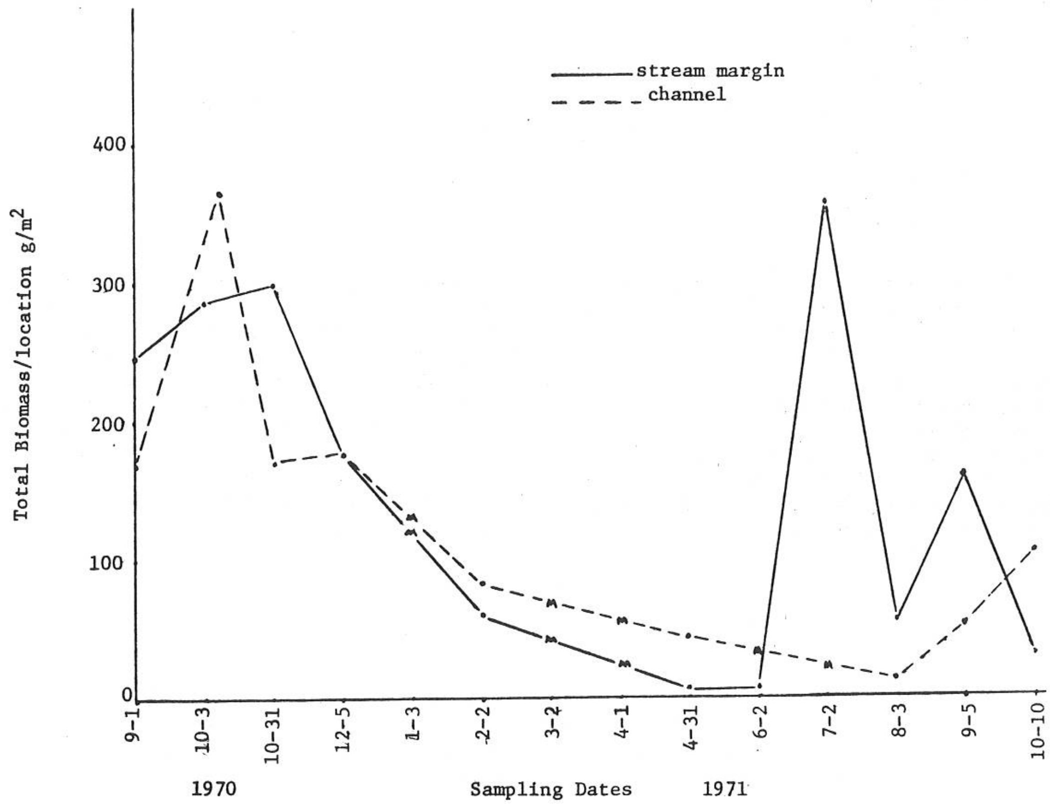


Figure 14. Total macrophyte biomass in each of the two sampling areas at Station 1, Deep Creek, Curlew Valley

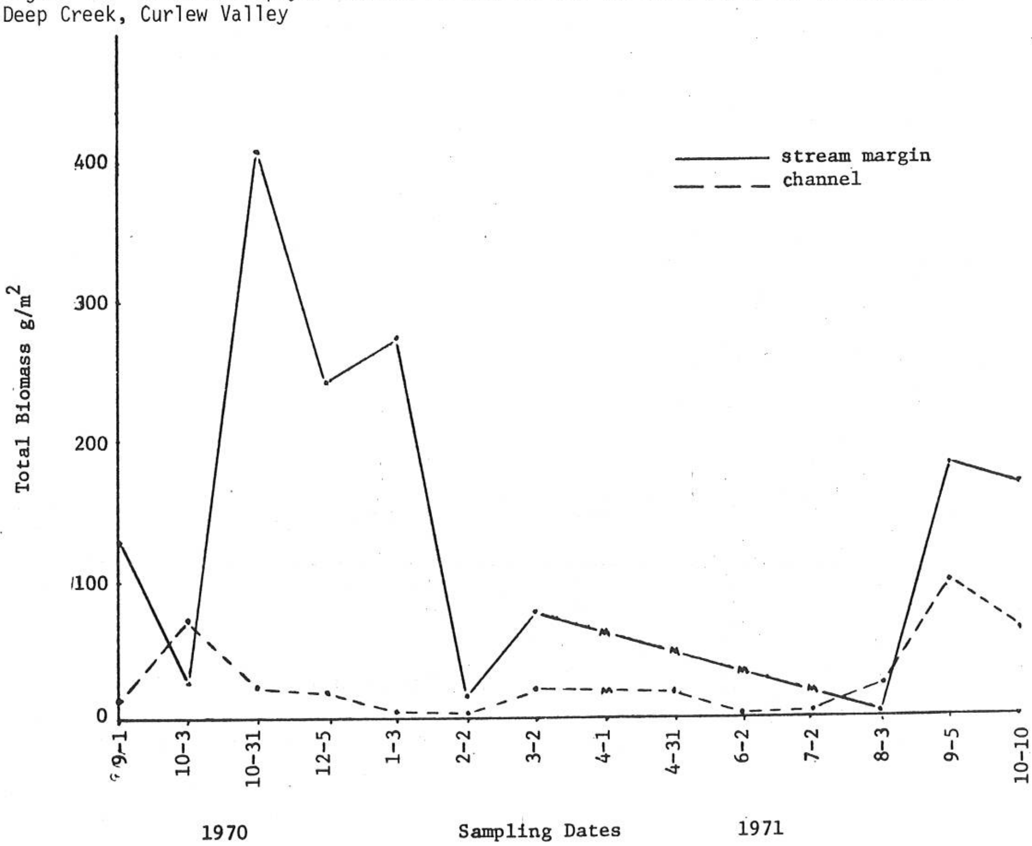


Figure 15. Total macrophyte biomass for each of two sampling areas at Station 2, Deep Creek, Curlew Valley.

At stations 3 and 4 the data for total macrophyte biomass are quite similar. Samples were not collected at these stations from October, 1970, through May, 1971. This was due to an almost complete removal of living material in the autumn, followed by complete ice-up during the winter months, and subsequently followed by exceedingly high water which persisted through the May, 1971, sampling date. Therefore, macrophyte biomass data are limited both at stations 3 and 4. It should be noted that the stream at these two stations has an entirely different chanacter than at those locations above the reservoir. At station 3 and 4 the stream has much deeper, slower moving water and a predominantly mud substratum. Total macrophyte production at both stations rarely exceeded 200 $g/m^2$ either along stream margin or in the channel (Figs. 16 and 17). Peak production at both stations and in both locations appeared to peak during August.

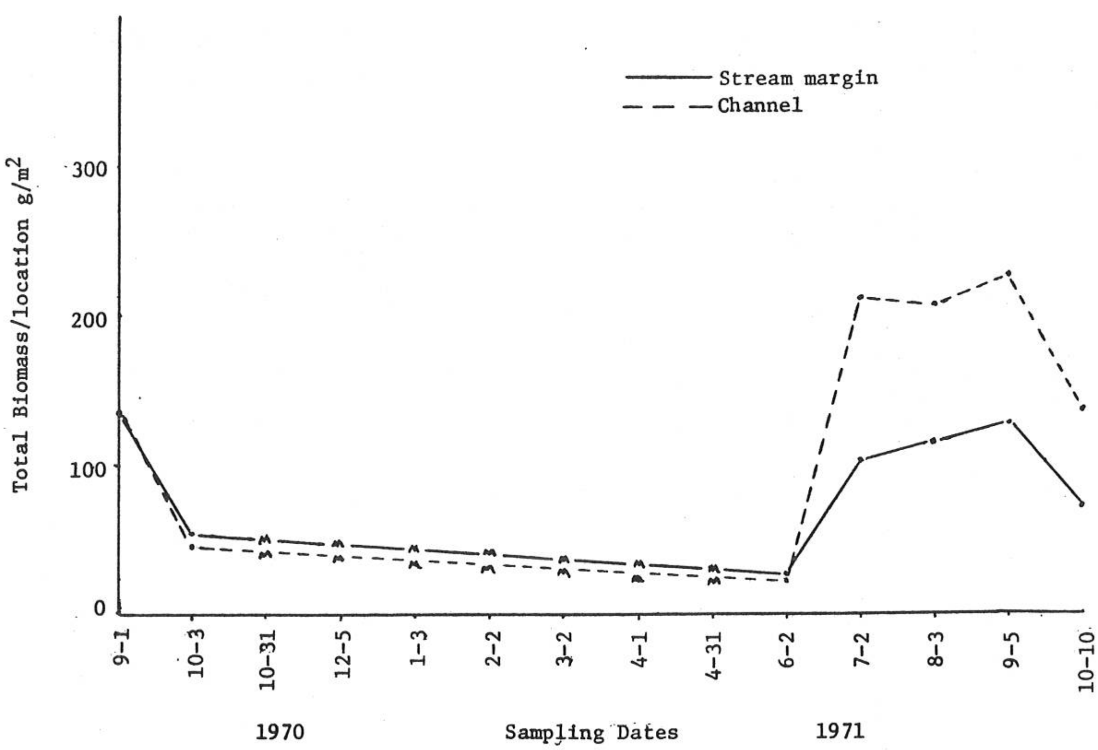


Figure 16. Total macrophyte biomass in each of two sampling areas at Station 1, Deep Creek, Curlew Valley.

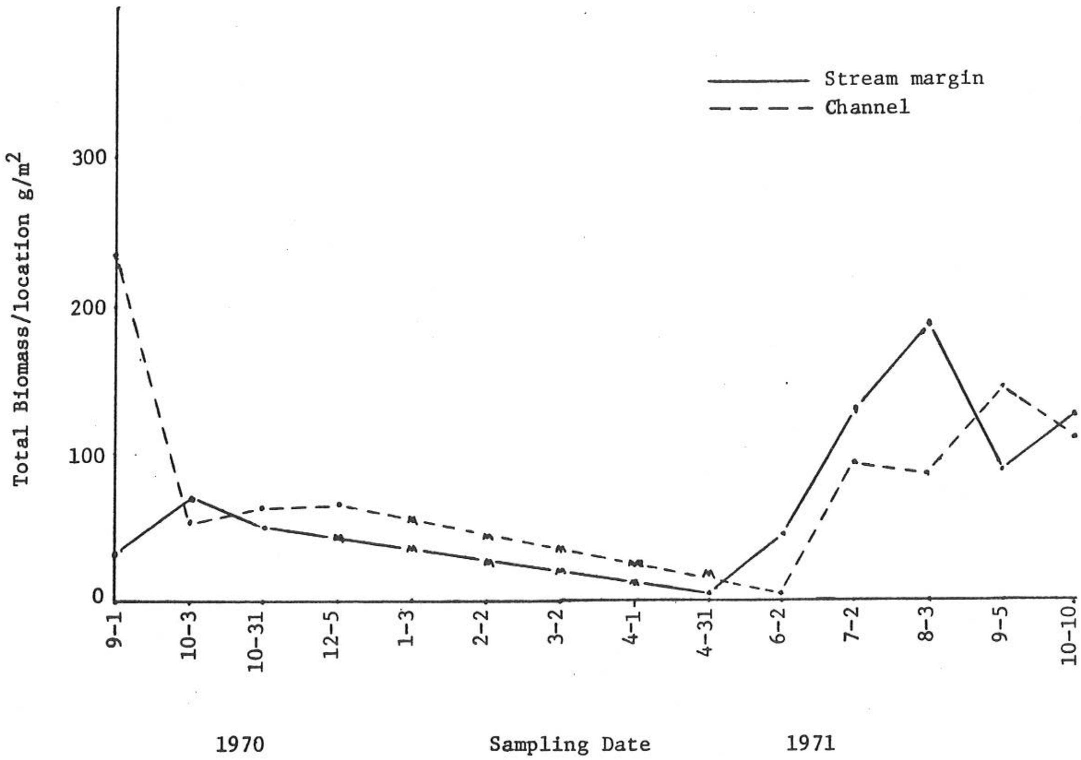


Figure 17. Total macrophyte biomass in each of two sampling areas at Station 1, Deep Creek, Curlew Valley.

Dominant species which contributed the major portions of total macrophyte biomass included *Chara vulgaris, Eleocharis macrostachya,* and *Potamogeton pectinatus*. Occasionally water cress (*Rorripa nasturtium-aquaticum*), red top (*Agrostis alba*), and *Potamogeton fififormis* contributed significant amounts at certain stations. At station 1, *C. vulgaris* was by far the dominant form of vegetation (Fig. 18). Although this is, in fact, a macroscopic alga, it was included with the other macrophytic plants because it constituted such an important portion of the total plant biomass at that station. During the fall of 1970, biomass of *C. vulgaris* at station 1 commonly exceeded 200 $g/m^2$, with a peak of 400 $g/m^2$ occurring at the time of the October sampling. Production of *C. vulgaris* was reduced significantly during the summer of 1971. This may have been due to the excessive scouring action to which it was exposed during the period of high run-off in the spring of 1971. *Chara vulgaris* also was an important dominant in the vegetation at station 3 with levels exceeding 100 $g/m^2$ observed in September, 1971.

*Eleocharis macrostachya* was also abundant along the stream margin at station 1 (Fig. 19). Biomass of this species exceeded 150 $g/m^2$ during the early fall of 1970 and the plant showed impressive growth during the period June 2 to July 2, 1971. However, at the time of the next sampling (August, 1971), the biomass of *E. macrostachya* declined from a level in excess of 300 $g/m^2$ to less than 50 $g/m^2$. This reduction was undoubtedly due to the grazing of cattle which were introduced into the area of the stream in which station 1 is located. During the fall of 1971, *E. macrostachya* was also an important contributor to the total biomass in the stream margin portions at stations 2 and 3 with levels exceeding 100 $g/m^2$ measured at both of these locations.

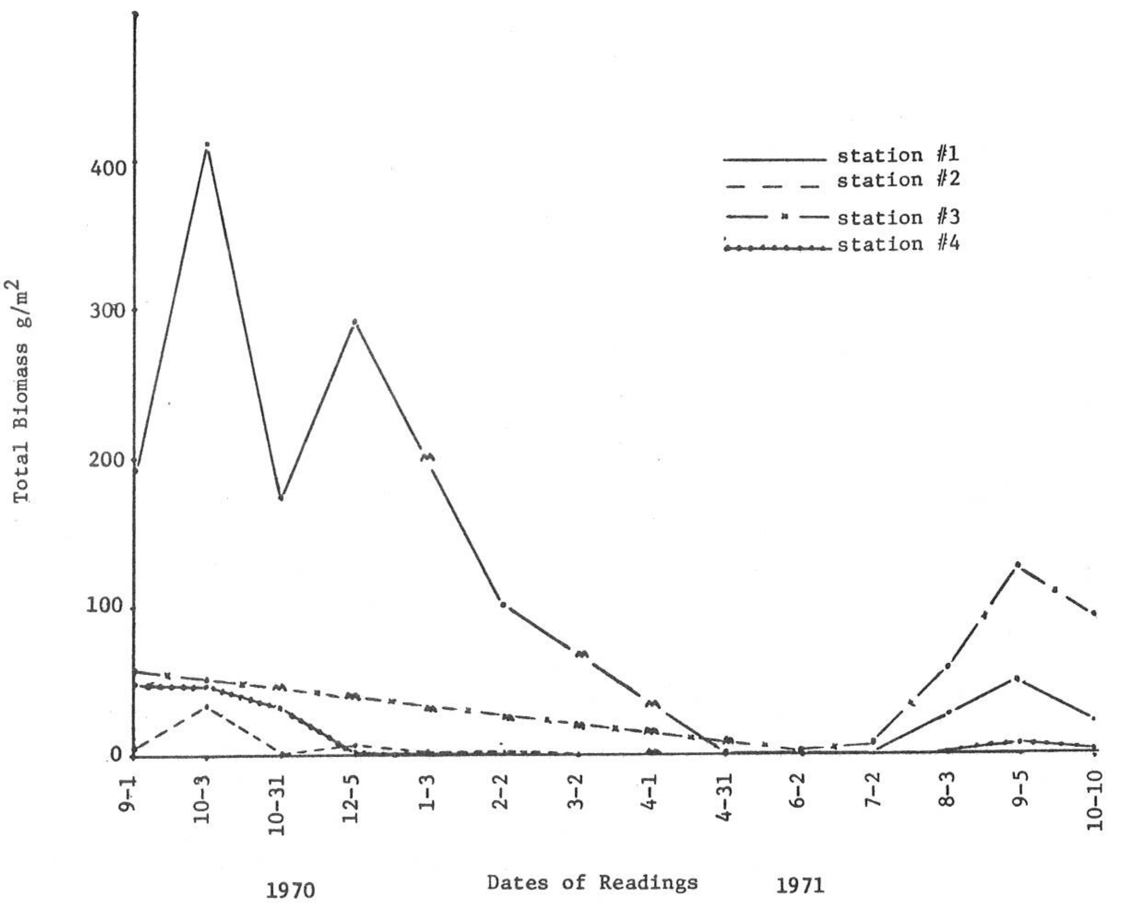


Figure 18. Total biomass of *Chara vulgaris* at each station in Deep Creek, Curlew Valley.

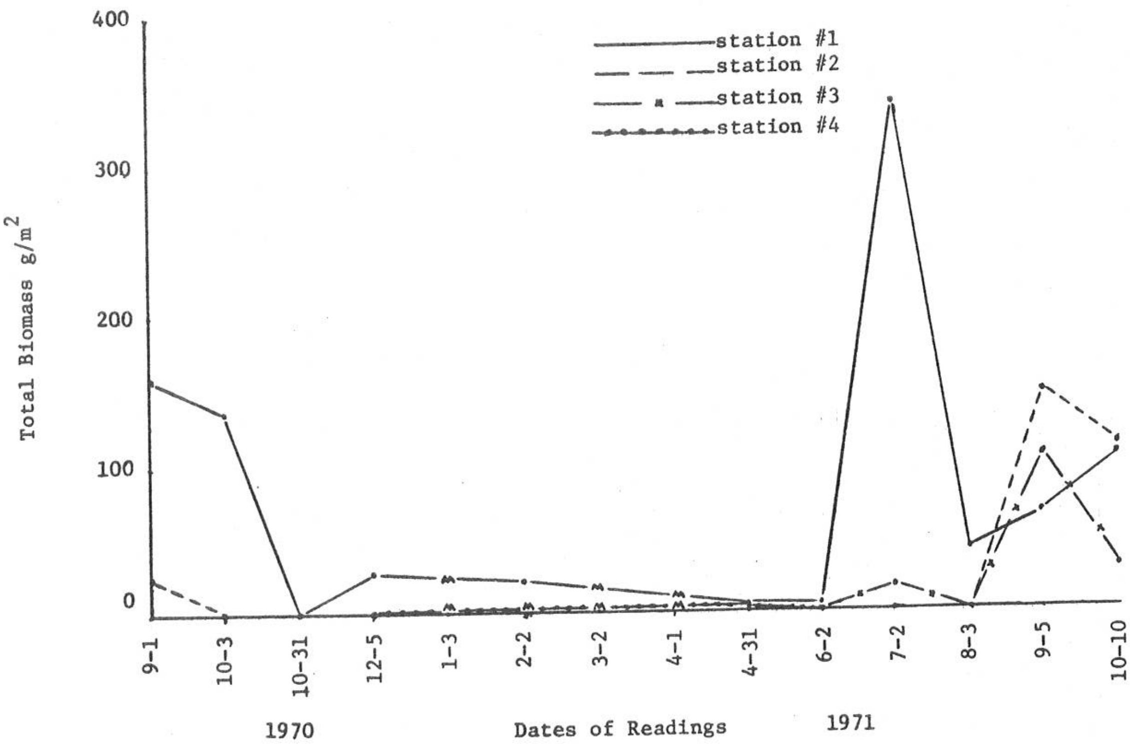


Figure 19. Total biomass of *Eleocharis macrostachya* at each station in Deep Creek, Curlew Valley.

The two stations located downstream from Curlew Reservoir were typified by large amounts of *Potamogeton pectinatus* (Fig. 20). Total biomass of this species exceeded 200 g/m$^2$ in September, 1970, and approached 300 g/m$^2$ at station 3 by July, 1971. This species did not occur in any of the samples at station 1 and only on limited occasions at station 2. Water cress (*Rorippa nasturtium-aquaticum*) was of consequence only at station 2. Total biomass of this species (Fig. 21) never exceeded 100 g/m$^2$. This was somewhat surprising in that gross examination of the area of the stream in which station 2 is located sometimes revealed extensive beds of water cress growing along the stream margin.

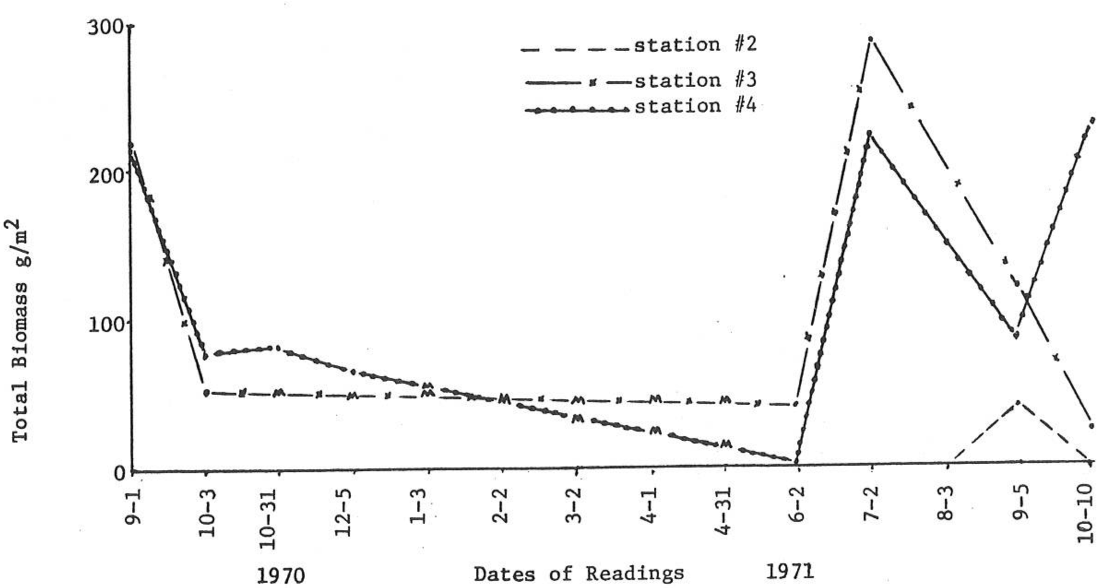


Figure 20. Total biomass of *Potamogeton pectinatus* at stations 2, 3, and 4, Deep Creek, Curlew Valley.

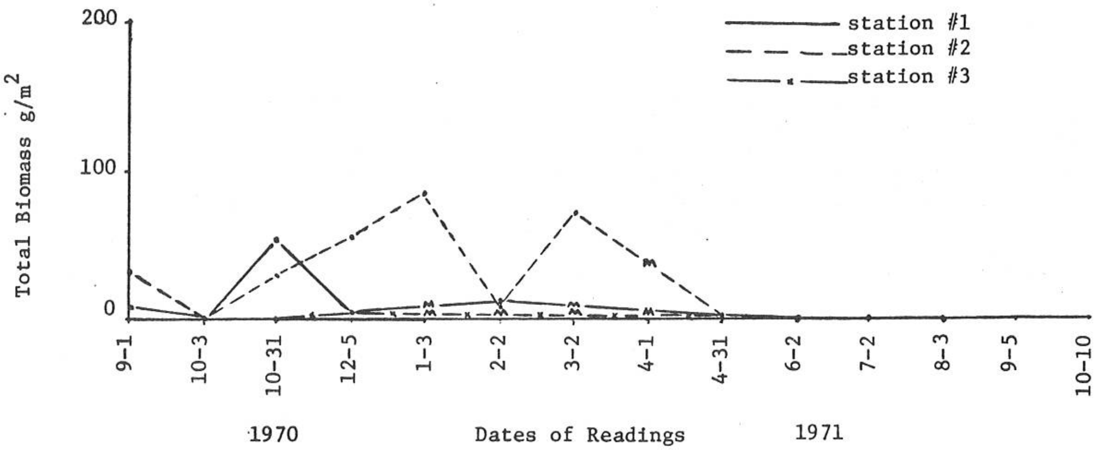


Figure 21. Total biomass of *Rorippa nasturtium-aquaticum* at stations 1, 2 and 3, Deep Creek, Curlew Valley.

*Potamogeton filiformis* was found at station 2 although it did not occur at any of the other stations. This plant was restricted to the channel portion of the stream and appeared to be the only macrophyte of any consequence. The total biomass of this species never exceed 75 g/m$^2$ (Fig. 22), yet it occurred in samples throughout the year.

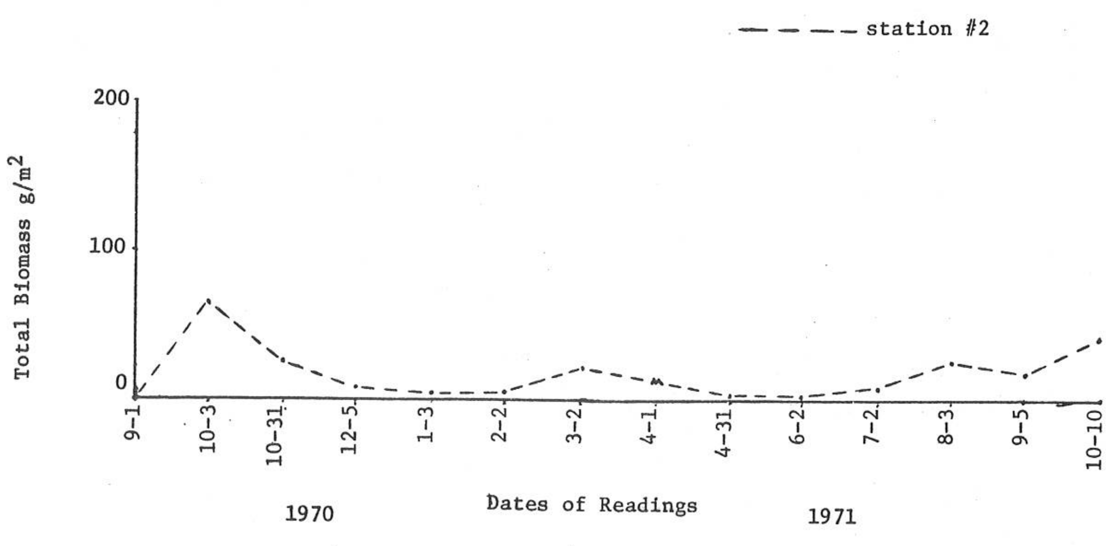


Figure 22. Total biomass of *Potomogeton filiformis* at Station 2, Deep Creek, Curlew Valley.

## J. COMMUNITY METABOLISM

The results of community metabolism measurements made in 1971 are given in Table 25; it is planned to repeat these measurements again in 1972. Highest net primary productivity was obtained at stations 2 and 3 in March, but even then it was not particularly high relative to other sources. The previous year (25 March, 1970), before the 1971 flood removed the masses of macrophytes at station 2, a value of 21 g $C/m^2/day$ was obtained. Except for station 2, photosynthesis to respiration ratios exceeded 1 only during the early part of the growing season, implying either rapid growth and production of biomass during the first part of the season only and simply maintenance of standing stocks thereafter, or heterotrophic growth during much of the season. At present, our observations favor the former explanation.

Table 25. Primary productivity, diel respiration and P:R ratios for Deep Creek, Curlew Valley, in g $C/m^2/day$ for 1971.

| Station | | 4 Jan. | 30 Mar. | 16 June | 14 July | 3 Aug. | 25 Sept. |
|---|---|---|---|---|---|---|---|
| 1 | $NP_{DL}$ | 0 | 0 | .39 | .63 | .86 | .54 |
| | $GP_{DL}$ | 0 | 0 | .51 | 3.98 | 1.16 | 1.45 |
| | $R_{24}$ | - | - | .47 | 6.85 | 1.57 | 1.90 |
| | $GP/R_{24}$ | - | - | 1.09 | .58 | .74 | .76 |
| 2 | $NP_{DL}$ | .71 | 4.82 | .26 | .55 | .19 | 1.80 |
| | $GP_{DL}$ | 2.91 | 8.09 | .38 | .74 | .50 | 3.08 |
| | $R_{24}$ | - | 5.33 | .33 | .40 | 1.00 | 2.25 |
| | $GP/R_{24}$ | - | 1.52 | 1.15 | 1.85 | .50 | 1.37 |
| 3 | $NP_{DL}$ | 0 | 8.66 | .40 | 1.32 | .70 | .93 |
| | $GP_{DL}$ | 0 | 12.65 | .60 | 1.69 | .87 | 1.88 |
| | $R_{24}$ | - | - | .15 | .09 | .26 | .17 |
| | $GP/R_{24}$ | - | 1.12 | .32 | .26 | .38 | .69 |
| 4 | $NP_{DL}$ | 0 | .90 | .21 | | .89 | 1.13 |
| | $GP_{DL}$ | 0 | 2.15 | 1.12 | | 1.26 | 2.14 |
| | $R_{24}$ | - | 2.56 | 4.50 | | 1.73 | 2.39 |
| | $GP/R_{24}$ | - | .84 | .25 | | .73 | .90 |

Of the many constructive insights that the community metabolism measurements for Deep Creek have provided thus far, perhaps the most important is the fact that carbon, rather than phosphorus or nitrogen, appears to be the main factor limiting primary production during the growing season. This is so even though bound and half-bound carbonate supplies remain high. For example, in July at station 3 under conditions of normal insolation, photosynthesis occurred for only a short time in the morning during which time the pH rose from below 8.00 to 8.87. By noon photosynthesis had ceased and pH values remained above 8.80 most of the afternoon. Chemical analyses of a water sample collected after photosynthesis had ceased yielded a total phosphate value of 0.21 mg/l, all of which was in the ortho-P form, a nitrate value of 0.12 mg/l and an ammonia value of 0.27 mg/l; bicarbonate alkalinity was about 265 mg/l. Other investigators have noted that in waters of pH between 8 and 9, carbon limitation may be important because the free carbon dioxide is low and the dissociation from bicarbonate to free carbon dioxide may not be nearly instantaneous, as presumed in the past. To inhibit photosynthesis, the lag need be only a few minutes: for example, a shift in pH from 8.5 to 8.2 may double macrophyte photosynthesis (Wetzel, 1970).

# DISCUSSION

The most outstanding event that occurred in Deep Creek to date was the flood of March, 1971. This flood resulted in discharges much higher than normal and provided a flushing action that removed plants and animals. The high water, from snowmelt runoff over frozen ground, also caused a drop in stream temperature, an increase in turbidity, and channel changes, especially at station 1 and 2. It appears that the extent and duration of spring runoff exert an overriding influence on the subsequent development of the stream biota, and under severe conditions (such as 1971) it can have significant long-term effects (extending over several years). For example, dense growths of water cress, which predominated over much of the stream at station 2 before the flood, still show no sign of recovery. In addition to the flood, 1971 was marked by unusually cool and wet conditions during much of the growing season, which appear to have had a profound effect on the stream and the riparian subsystem. Therefore, it is presently impossible to characterize the ecosystem in terms of more normal or desert-like conditions. It is hoped that 1972 will provide the opportunity for such characterization.

A variety of important events occurred at the individual stations throughout the study period. At station 1 during the summer of 1970, a large herd of cattle had a pronounced effect on the stream: they wore down the stream banks and cropped or trampled the vegetation near the stream, thus having immediate and long-term effects on water turbidity and sedimentation. Large amounts of cattle wastes caused water chemistry changes. In 1971 the cattle were not present near the collecting station until early autumn but were present throughout the summer about 2 km upstream, thus reducing their effects on this station. From late spring through summer, thunder showers occasionally caused flash-floods, with as much as a 1- to - 1.5 m high wall of water moving down the stream channel.

Station 2 has a spring source and therefore has a fairly constant flow. During the summer, however, three-fourths of the normal discharge periodically is diverted into an irrigation ditch. The result of this diversion is a drop in discharge and current at the sampling station and a gradual rise in water temperature. This diversion usually begins in May, but normal flow is resumed at various times and for varying lengths of time throughout the summer and early autumn. These surges of flow during an already critical time of the year appear to have a serious impact on the biota.

At station 3, livestock (cattle, horses, sheep) have access to the stream both above and below the sampling site. During the autumn of both 1970 and 1971, a prolonged period of heavy turbidity resulted from the loss of the lush growth of aquatic vegetation at this station. It appears that in September-October respiration greatly exceeds photosynthesis, eventually resulting in anaerobic conditions. At this time massive amounts of hydrogen sulfide (and methane) are produced in the organically-rich sediments which stir-up the bottom materials (see Lee, 1970), dislodge the rooted macrophytes, and deoxygenate the overlying water. At this same time a dramatic reduction in the number of fish occurs.

Station 4 is affected by the adjacent reservoir and by riparian vegetation. The collecting station is about 1.5 km below a reservoir and changes in the release of water cause variations in discharge which affect the turbidity and suspended organic matter (of which former planktonic forms make-up a significant fraction). Leaf-fall and shade from willows and roses also have important effects on this section of the stream. Except for the winter of 1971-1972, cattle were absent from this study area.

During the study a number of important land-water interactions have been observed, including (1) the effect of cattle, both from direct disturbance and through the addition of nutrients, (2) the effect of different land-use patterns on water quality and volume of runoff, (3) the effect irrigation use on ecosystem structure and production in the stream, and (4) the effect of aquatic vegetation on the availability of water for irrigation. As demonstrated by the work on Sycamore Creek, the importance of desert aquatic systems to the land is greatest during periods of drought. Yet even under the relatively wet, cool conditions of 1971 the importance of such areas (and the interplay between land and water thus effected) was shown in Deep Creek for such things as: the general composition and success of the riparian flora and fauna (especially insects and spiders) which in turn affected the composition and survival of various songbirds and small mammals; the survival and success (in terms of honey production) of domestic bees; production of upland game birds, waterfowl, muskrats, and wild and domesticated ungulates; use of otherwise arid lands for crop production.

A flow diagram summarizing the principal energy (and carbon) pathways for the Deep Creek ecosystem is given in Figure 23. An important, but as yet unevaluated, circuit involved the input and transfer of allochthonous detritus, primarily from cattle manure. However, in Deep Creek the immediate source of energy appears to be from autochthonous sources; some is derived from living plants but most of it comes as detritus. If this analysis is correct then Deep Creek is unlike most of the streams studied thus far where allochthonous materials have proven to be of greatest importance. However, like the others, the economy of Deep Creek appears to be largely heterotrophic and to be carried over "lean" periods, outside of the growing season, by materials stored in the sediments.

A useful function of the model (Fig. 23) at this stage has been to provide a plan around which it has been possible to organize the various studies needed to achieve complete understanding of the functioning of this particular ecosystem. The validation work has been concerned with qualifying and quantifying the state variables given in the boxes, but a number of process studies are needed to establish the rate functions represented by the arrows. Especially important are those involving rates of ingestion and assimilation, respiration, and growth of the animals; metabolic rates of the decomposers; and rates of photosynthesis and respiration by the plants.

Over 150 kinds of organisms have been collected from Deep Creek, including 14 species of algae, 13 species of aquatic vascular plants, 119 taxa (mostly to species) of macroinvertebrates, and 5 species of fish. Except for the algae and microscopic invertebrates this is a fairly complete list. However, only about 27 of these (Table 26) account for most of the energy flow (although many others may play regulatory or otherwise critical roles). A limited amount of work has been done to establish energy budgets for the prime movers of energy, some of it under IBP support (Table 26 : d,e) but much of it by graduate students not supported by IBP. However, much more remains to be done and this area continues to be the major deterrent to the development of a quantified energy flow model for Deep Creek. Such studies, of course, fall within the realm of aquatic Process Studies, which have never received adequate support within IBP. The principal areas that remain unfinished involve microbial respiration, allochthonous input, and the energy budgets of the invertebrates and one species of fish.

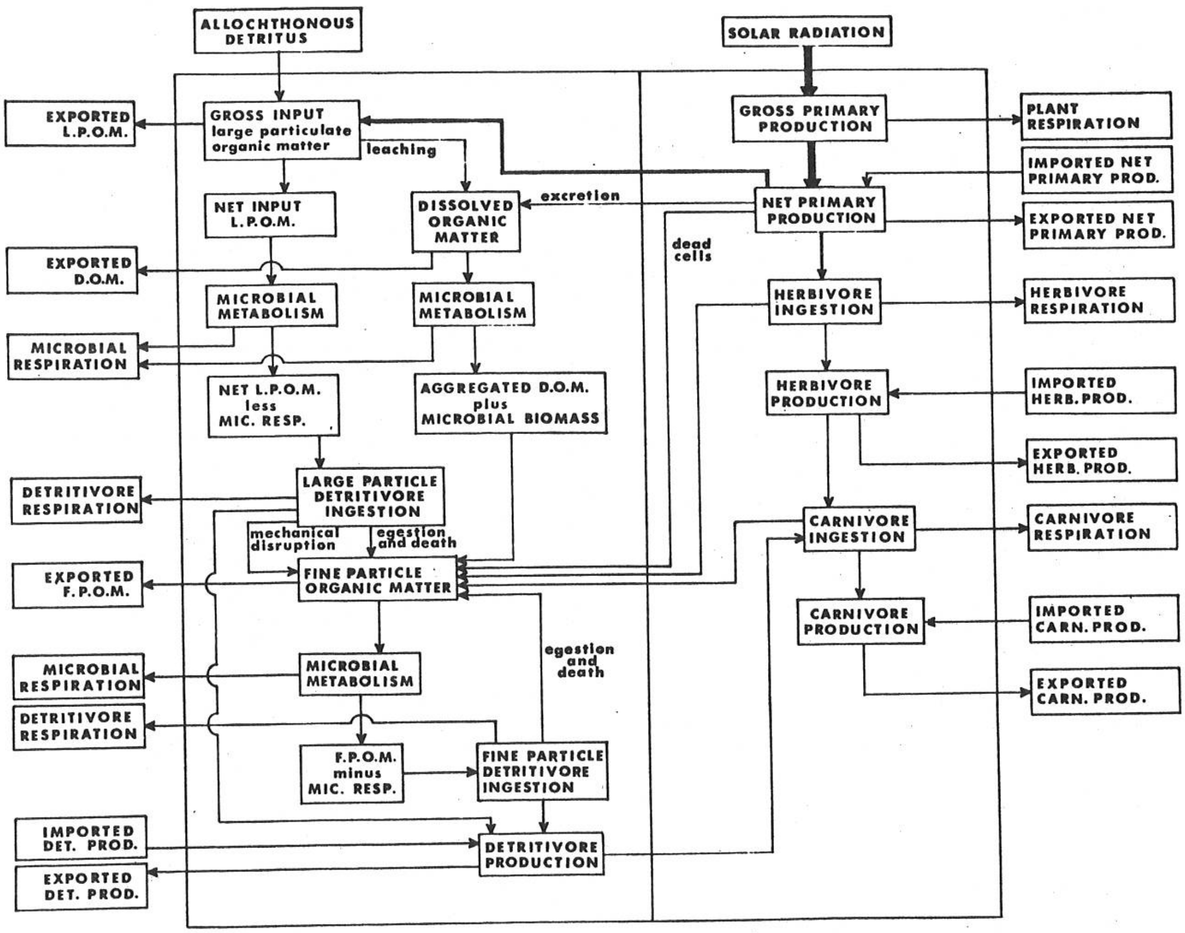


Figure 23. A flow diagram summarizing the present conception of energy relationships in the Deep Creek ecosystem. By convention the rectangular boxes designate state variables, the arrows designate rate functions (processes) and their direction. The large square box encompassses all of the items pertaining to energy flow contained within a given stream section; the line near the center separates the autotrophic and heterotrophic energy routes. Inputs and outputs of the system are located outside of the large box.

Table 26. Status summary for process studies relating to the Deep Creek, Curlew Valley validation site. The occurrence of each major taxon is indicated for each station by an "x" if it is important, by a "-" if present but not important, and by a "o" if absent. Studies which are completed or underway are designated by letter.

| Taxon | Station 1 | 2 | 3 | 4 | Food Habits | Ingestion and Assimilation | Respiration | Growth | Calorimetry |
|---|---|---|---|---|---|---|---|---|---|
| A. Plants | | | | | | | | | |
| Bacillariophyceae | - | - | - | - | | | | | |
| *Chara vulgaris* | x | x | x | x | | | | | |
| *Cladophora glomerata* | - | x | x | - | | | | | |
| *Eleocharis macrostachya* | x | x | - | o | | | | | |
| *Potamogeton pectinatus* | o | x | x | x | | | | | fg |
| *Rorripa nasturtium - aquaticum* | - | x | o | o | | | | | fg |
| B. Invertebrates | | | | | | | | | |
| *Bithinia* | o | o | x | o | | | | | |
| *Gyraulus* | o | o | x | - | | | | | |
| *Physa* | - | o | x | - | | | | | |
| *Pisidium* | x | o | x | x | | | | | |
| *Erpobdella punctata* | - | o | x | - | | | | | |
| *Helobdella elongata* | - | - | x | - | | | | | |
| *Tubifex* | - | - | x | - | | | | | g |
| *Gammarus lacustris* | - | - | x | o | a | | | | |
| *Hyalella azteca* | x | x | x | x | a | | d | | cf |
| *Pacifastacus gambelli* | o | x | - | o | | | | | g |
| *Baetis tricaudatus* | x | x | - | - | a | | | | f |
| *Tricorythodes minutus* | - | x | - | - | a | b | b | h | cf |
| *Enallagma anna* | - | - | x | - | a | b | cd | | c |
| *Ophiogomphus severus* | - | x | o | x | a | | c | | c |
| *Deronectes striatellus* | x | - | o | o | | | | | |
| *Dubiraphia guilianii* | - | - | x | - | | | | | f |
| *Optioservus divergens* | - | x | x | - | | | | | c |
| *Hydropsyche occidentalis* | x | x | x | - | a | b | cd | | cfg |
| Chironomidae | x | x | x | x | | | | | fg |
| *Simulium* | x | x | - | x | a | | | | |
| C. Fish | | | | | | | | | |
| *Rhinichthys osculus* | x | x | x | x | | | e | | g |

a. Dale Koslucher, Idaho State University (also *Limnephilus frijole* and *Sigara*)
b. Dale McCullough, Idaho State University
c. Dennis Brass, Idaho State University
d. Arden Gaufin, University of Utah
e. Robert Kramer, Utah State University
f. Advanced Limnology Class 1970, Idaho State University
g. Advanced Limnology Class 1971, Idaho State University
h. Robert Newell, Idaho State University

One very useful study (Koslucher, 1971) involved a description of the food habits of a number of common benthic invertebrates in Deep Creek and has increased our understanding of important interrelationships within the community (Fig. 24). However the rates of transfer remain to be quantified and other species, since found to be important, remain to be studied. Of the eleven species studies over a year's time, two (*Hydropsyche occidentalis* and *Limnephilus frijole*) were herbivores and consumed mainly diatoms. Six species (*Hyalella azteca, Gammarus lacustris, Baetis tricaudatus, Tricorythodes minutus, Sigara* sp., and *Simulium* sp.) were detritivores, and three (*Enallagma anna, Argia vivida,* and *Ophiogomphus severus*) were carnivores. Of the three predominant food groups consumed by the invertebrates in Deep Creek (detritus, diatoms, and insects), autochthonous detritus, derived from aquatic vascular macrophytes and mats of *Chara* and *Cladophora*, was the major food source. In Deep Creek the foods eaten were consumed in amounts that matched their concentrations at each station, indicating that many of the benthic invertebrates are opportunistic feeders.

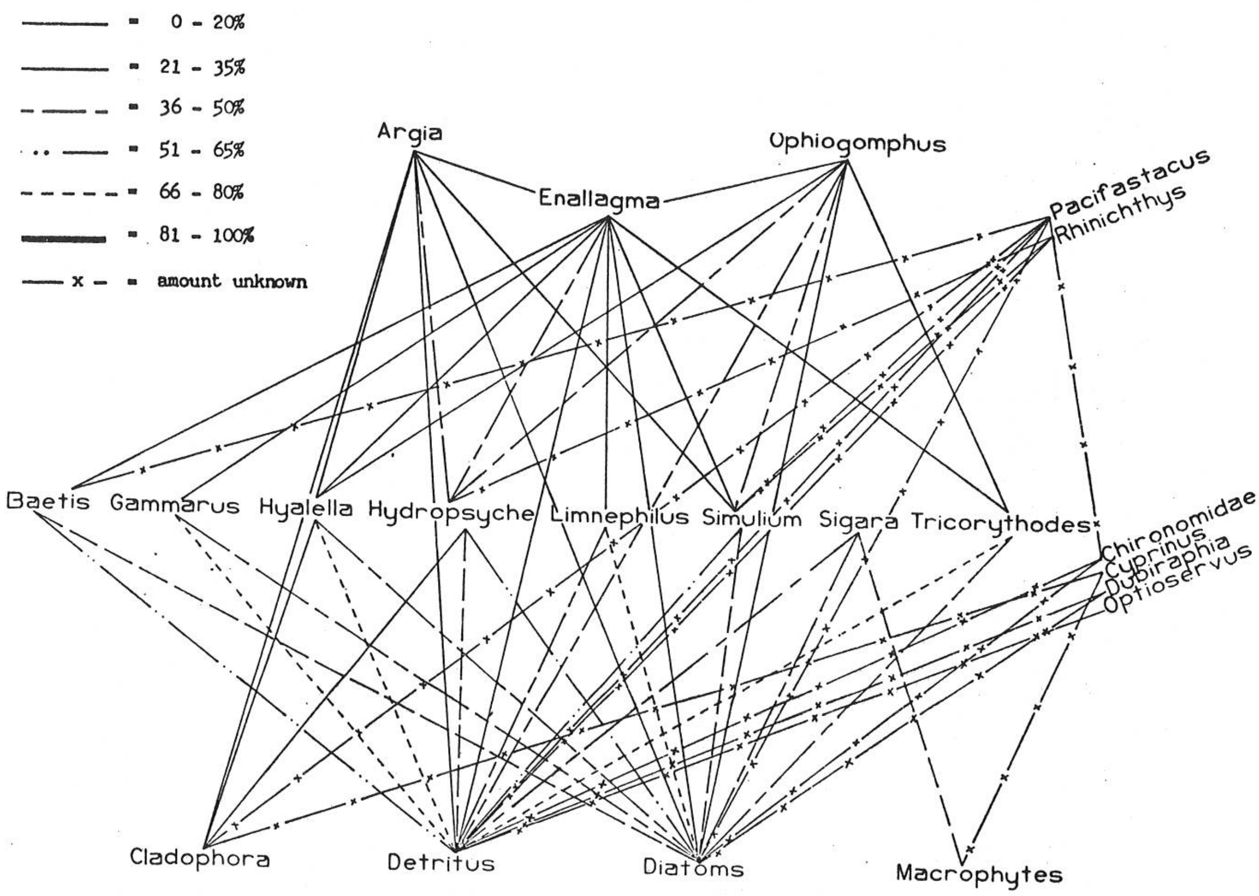


Figure 24. Composite food web of Deep Creek (from Koslucher, 1971).

# EXPECTATIONS

It is planned to continue the study through August, 1972, at which time two full years of concurrent data collection will be completed. An independent application has been made to the National Science Foundation to continue some of the work begun on ecosystem dynamics and to use the information gained thus far to develop solutions to applied problems related to the use of waters in arid regions. If successful, we intend to continue our close affiliation with the Desert Biome program.

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